OPEN MEETING AGENDA ITEM

ORIGINAL

MEMORANDUM

0000145981

TO: Docket Control
Arizona Corporation Commission

FROM: Steven M. Olea
Director
Utilities Division

DATE: June 28, 2013

RE: INVESTIGATION OF SMART METERS (Docket No. E-00000C-11-0328)

Staff is submitting the following three reports regarding the health effects of smart meters for review. These reports include:

- Public Utility Commission of Texas, Project No. 40190, Project Relating to Advanced Metering Issues (2012).
- Vermont Department of Health, Radio Frequency Radiation and Health: Smart Meters (2012).
- Richard Tell Associates, An Evaluation of Radio Frequency Fields Produced by Smart Meters Deployed in Vermont (2013).

Staff submits these reports for informational purposes. If the Commission desires to have its own independent study of the health effects of smart meters, Staff recommends that the Commission request that such a study be conducted by the Arizona Department of Health Services.

SMO:EAH:tdp/MAS

Originator: Eric A. Hill

Arizona Corporation Commission
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Service List For: Generic Investigation - Energy Policy Act of 1992
Docket No: E-00000C-11-0328

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ATTACMENT 1

Donna L. Nelson
Chairman

Kenneth W. Anderson, Jr.
Commissioner

Rolando Pablos
Commissioner

Brian H. Lloyd
Executive Director

Rick Perry
Governor

Public Utility Commission of Texas

Date:	December 17, 2012
To:	Chairman Donna L. Nelson Commissioner Kenneth W. Anderson, Jr. Commissioner Rolando Pablos
From:	Alan Rivaldo Infrastructure & Reliability Division
Subject:	Project No. 40190, Project Relating to Advanced Metering Issues *Report on Health and Radiofrequency Electromagnetic Fields from Advanced Meters*

Recently, some citizens of Texas have expressed concern over the potential health effects of exposure to the radiofrequency emissions from the wireless technology of advanced metering. Some of these individuals have appeared before or submitted comments to the Commission (under Project 40190, *Project Relating to Advanced Metering Issues*) and the Texas Senate Committee on Business and Commerce (at http://www.senate.state.tx.us/75r/senate/commit/c510/c510.htm).

Some have relied on social media as a source of information because it disseminates ideas rapidly and widely, but it also can be inaccurate and lack objectivity. Therefore, Staff decided to investigate the health concerns expressed by citizens and other interested parties. The product of this investigation is the attached document intended to objectively address the issue and help inform decision makers. Staff reviewed recent research on the potential health effects of radio frequency electromagnetic field (RF EMF), reported on the findings, and assessed disputes regarding the findings.

Staff found many scientific research papers published on the effects of EMF on health over a period of nearly 90 years; they number in the thousands. Despite this extensive body of work, scientific research continues, and dozens of papers are published each year.

Staff has determined that the large body of scientific research reveals no definite or proven biological effects from exposure to low-level RF signals. Further, Staff found no credible evidence to suggest that advanced meters emit harmful amounts of EMF.

While many different organizations have performed primary research on health and RF EMF, Staff relied heavily on the following sources:

1. The California Council on Science and Technology (CCST), an independent state agency, assessed the available evidence of whether FCC standards provide sufficient protection of public health. Its report also questioned whether additional standards are needed to ensure adequate protection from adverse health effects of wireless communication technology.
2. The Michigan Public Service Commission requested help from Lawrence Berkeley National Laboratory (LBNL) in assessing claims made by some individuals who refuted the findings of the CCST report. The PUCT report summarizes the LBNL work.
3. The measurements and assessments performed by the Electrical Power Research Institute (EPRI), an organization that performs research and provides technical expertise to the electrical utility industry.

Staff found the CCST conclusions, LBNL's work, and the investigations by EPRI to be highly credible and based on sound scientific principles.

Other material Staff reviewed, found valuable, and used to inform the report came from:

- The federal government (FCC, NIH, and other agencies);
- The Canadian government and its provincial health authorities;
- Countries in Western Europe;
- Several municipalities deploying advanced meters;
- Various governmental entities in Australia;
- Academia;
- The United Nations' World Health Organization;
- Utility industry organizations; and
- International standards-settings organizations.

Alan Rivaldo is available to answer any questions you may have.

Health and RF EMF from Advanced Meters

An Overview of Recent Investigations and Analyses

Public Utility Commission of Texas
Infrastructure & Reliability Division
Staff Report

Prepared by Alan Rivaldo
Project No. 40190

December 2012

This document is work supported by the Department of Energy under award numbers DE-OE0000092 and DE-OE0000180.

Any views presented in this paper do not necessarily represent a Commission decision.

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Executive Summary

This paper is a survey of existing scientific research and analyses that have been performed to investigate the potential health effects of exposure to low-level radio frequency electromagnetic fields emitted by wireless communication devices including smart meters. No independent empirical research has been performed by Public Utility Commission of Texas (PUCT) staff, but the results of several studies are summarized in this report.

Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. Further, Staff reviewed all available material and found no credible evidence to suggest that smart meters emit harmful amounts of Electromagnetic Field (EMF) radiation.

Radiation comes in two forms: ionizing and non-ionizing. The methods of data transmittal by smart meters most common in Texas (which communicate wirelessly) and other forms of telecommunications (television, radio, cell phones, satellite) utilize non-ionizing EMF radiation in the Radio Frequency (RF) band, commonly known as RF EMF.

In contrast, ionizing radiation carries an inherently greater amount of energy; it may come from the decay of fissionable material like uranium or from EMF at significantly higher frequencies, such as X-rays or cosmic rays. Because of its inherent high energy, ionizing radiation is known to cause cellular disruption which may lead to various acute or chronic medical problems, including the induction of cancer.

Smart meters do not emit or utilize ionizing radiation.

RF EMF can cause the heating of living tissue (thermal effect) when the tissue is exposed to a certain level of intensity, which is the only known risk of exposure to such emissions. The Federal Communications Commission (FCC) has therefore established two tiers of Maximum Permissible Exposure (MPE) - one tier applies if exposure occurs in an occupational or "controlled" situation, and the other tier applies if the general population is exposed or exposure results from an "uncontrolled" situation. The FCC uses a safety factor for the general population tier that sets the MPE at 1/50th of the level of known thermal effects while the occupational MPE is set at 1/10th of the level. Because smart meters are devices deployed among the general population, the more restrictive of the two safety factors is applied; the MPE for the general population is 80% lower than the occupational MPE.

Many governmental health agencies from around the world, including those at the state, provincial, county, and city levels, in addition to academic institutions and other researchers have stated that there are no known non-thermal effects from exposure to RF EMF. This lack of non-thermal effect includes the effects which manifest from exposure to ionizing radiation. Nonetheless, substantial medical research on any potential non-thermal effects of non-ionizing radiation has been conducted and is ongoing. It is anticipated that medical researchers will continue to perform investigations of both the potential thermal and non-thermal health effects of RF for the foreseeable future.

It is important to note that one must use caution when relying solely on the results of individual research studies because conflicts or inconsistencies may exist among the results of other individual studies. Laymen often may not recognize poorly executed studies, or they can misinterpret the results of properly conducted scientific research. Either circumstance may lead a casual observer to draw errant conclusions. Furthermore, it is impossible to scientifically prove absolute safety (the null hypothesis).

The Electric Power Research Institute (EPRI) has undertaken several substantial investigations of smart meter RF EMF, and found that smart meters comply with the FCC MPE requirements. Furthermore, it found that in-residence exposure to the emissions from a smart meter is greatly mitigated by several factors:

- The intensity of RF EMF is reduced *exponentially* with greater distance from the emitting device;
- The shielding provided by the meter enclosure;
- The home's building materials further weaken the field strength;
- The meter antenna orientation inhibits the inward direction of the field pattern; and
- RF EMF emissions are only intermittent; a smart meter typically transmits 1 - 5% of the time.

Several governmental entities such as the City of Naperville in Illinois, the Vermont Department of Health, the Victorian State Government of Australia, and the City of Richmond in British Columbia, Canada have performed their own tests on RF EMF from smart meters. These tests corroborated the results of EPRI's investigations.

Some smart meter opponents have raised the concern that the meters may interfere with other electronic devices. Smart meters typically communicate using the 902-928 MHz frequency band which is unlicensed spectrum and falls in the vicinity of where some cordless telephones operate. The FCC's technical rules mitigate the potential for the meters to interfere with other electronic devices by requiring them to be tested and certified as compliant with these rules before they can be marketed. Financial penalties can be assessed if one does not comply with the appropriate FCC equipment authorization procedure.

Despite a lack of credible evidence, opponents have challenged the use of common devices that emit RF EMF on the basis of health and environmental concerns. Some of these concerns involved cell phones and towers, some focused on the use of Wi-Fi[1] in schools, and a few were specifically related to smart meter deployments. As a result of concerns about the wireless technology employed by smart meters, the California state legislature commissioned the California Council on Science and Technology (CCST) to perform a study. The CCST, an independent, non-profit organization, solicited input from technical experts and reviewed and evaluated available research information about health impacts of RF emitted by electric appliances and smart meters. The CCST report concluded that:

- The exposure to RF from smart meters was lower than that from many household devices;
- The FCC standard provides adequate protection from known thermal effects;
- There were no identified non-thermal health effects from existing common household devices, including smart meters; and
- There was no call at this time for devising standards to govern the non-thermal effects of RF exposure.

In response to these findings, various parties opposed to smart meters filed comments with the California Public Utilities Commission which questioned or conflicted with the conclusions of the CCST report. As a result, the Michigan Public Service Commission asked Lawrence Berkeley National Laboratory (LBNL) to review the assertions made in those comments. EPRI also provided its opinions on the submitted comments separately. EPRI found that the submitted comments ignored a substantial amount of existing evidence and that the content indicated a general misunderstanding of concepts and basic principles about smart meters. LBNL was far more critical of the meter opponents' comments in its response and provided greatly detailed assessments of what it viewed as shortcomings of the submittals.

[1] Wi-Fi is a popular technology that allows an electronic device to exchange data wirelessly using radio waves over a computer network, including high-speed Internet connections. Wi-Fi products are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards.

Some opponents of smart meters have raised the idea of the existence of Electromagnetic Hypersensitivity (EHS), a condition in which certain people seem to be especially susceptible to EMF, exhibiting a wide range of physical afflictions. The World Health Organization (WHO) has issued documents on the topic, including recitations of a number of studies which had been conducted on individuals claiming to suffer from EHS. The studies typically attempted to elicit symptoms under controlled laboratory conditions. The WHO concluded that the symptoms experienced by those who have been described as being hypersensitive were not correlated with EMF exposure, and therefore there was no scientific basis to link EHS symptoms to EMF exposure. It suggested that symptoms experienced by some EHS individuals might arise from environmental factors unrelated to EMF or that the symptoms may be due to pre-existing psychiatric conditions or stress reactions resulting from worrying about EMF health effects, rather than the EMF exposure itself. Further, scientific studies show that people who are ill are highly receptive to negative suggestion and may demonstrate a "nocebo response" as a result of these suggestions.

A few people opposed to the use of wireless technologies have made claims that EMF can be used as a weapon to cause pain, disrupt thought, or alter or control human behavior. Smart meters do not have the capabilities to do these things.

Smart meters are designed to measure a customer's overall electricity usage and deliver that data to the utility. A meter may also offer a limited set of information to an end user if he desires. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions.

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Introduction

Some members of the public have expressed concerns over the possible health effects from exposure to electromagnetic fields (EMF) emitted by advanced meters that transmit data wirelessly (smart meters). People have stated their concerns in public forums hosted by the Public Utility Commission of Texas (PUCT) or submitted written comments to the agency. The comments are available on the PUC's website under project 40190.[2] Citizens have also appeared before the Texas Senate Committee on Business and Commerce[3] to make statements. This report is intended to inform decision makers and other parties interested in the topic.

Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. In reviewing all available material, Staff found no credible evidence to suggest that smart meters emit harmful amounts of EMF.

This paper begins by explaining radiation which is a word that has several meanings. This document explains the distinction between ionizing and non-ionizing radiation. Also discussed are some fundamental characteristics of radio-frequency EMF (RF EMF) which is the non-ionizing form of radiation utilized by almost all wireless forms of telecommunication and by smart meters that send data through the air.

Because properly understanding radiation and health depends upon understanding the foundations of science, this paper explains the scientific method and outlines what constitutes valid science. Some people have claimed that they can make scientific arguments against the use of wireless communications technology, or describe what they view as its egregious hazards, or produce evidence of harm. This document provides guidance when considering such assertions.

As new technologies continue to pervade our lives, matters of science are addressed more often by our legal system. Public policy must also address technology, and those who craft laws and regulations often rely on external sources to provide subject matter expertise in matters of science, including medicine. This was true for the California Public Utilities Commission (CPUC). CPUC asked the California Council on Science and Technology (CCST) to analyze submittals made by various experts in science and medicine regarding RF EMF.

CPUC received comments that were critical of the CCST report. Various parties responded in defense of the conclusions of the CCST report. This paper summarizes the CCST report, some of the reply comments, and responses to those comments. Staff found the CCST conclusions to be based on sound scientific principles.

Several entities, such as the Electric Power Research Institute (EPRI), have measured the level of RF EMF exposure one would receive from smart meters. This report summarizes the findings of the EPRI investigations as well as those performed by other organizations.

This paper discusses standards for human exposure to EMF and regulations that govern devices which emit EMF. This report provides statements from health agencies of several countries and those made by academia regarding human exposure to RF EMF. This document concludes with a discussion about a purported medical condition called electromagnetic hypersensitivity and the notion of using EMF as a weapon. A chart of acronyms and abbreviations follows, along with an alphabetized list of references and resources.

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2 <http://interchange.puc.texas.gov/WebApp/Interchange/application/dbapps/filings/pgControl.asp?TXT_UTILITY_TYPE=A&TXT_CNTRL_NO=40190>.

3 <http://bandc.posterous.com/updated-october-9-2012-agenda-with-links-57790>.

The Science

Background – Radiation, Science

The fear of things that cannot be seen is innate to human beings. Imagine being dropped off alone in a forest in the middle of the night, with no moon to light the way. Are there venomous snakes or scorpions underfoot? Are there other unseen threats nearby? RF EMF is also invisible, so some people may be predisposed to feeling anxious about it.

Fear of the unknown is also common, and to some people, the notion of wireless communications technology is new, or something with which they have no experience. To make matters worse, wireless technology is a form of electromagnetic radiation (EMR), and the term "radiation" is rather ambiguous and commonly misunderstood. Exposure to radiation has been traditionally associated with chronic illnesses (specifically cancer) and death. Lastly, microwave ovens use EMR to cook food and boil water; knowing this, some people may imagine themselves being cooked or boiled alive if exposed to EMR.

Radiation

Radiation can be characterized as energetic particles or waves traveling through matter or space. Radiation can come from natural or man-made sources. For this report, it is important to first know that there are two types of radiation: ionizing and non-ionizing. Making the distinction is crucial because the word "radiation" on its own can evoke images of the victims of the atom bomb or the outcomes of the Chernobyl and Fukushima Daiichi disasters, when in fact the many forms of radiation we encounter in our daily lives are inert.

Ionizing Radiation

Ionizing radiation can come in one of two forms: particulate (e.g. neutron, alpha, or beta particles) or electromagnetic (e.g. gamma, cosmic, or X- rays). Ionizing radiation has such a high energy level that when it hits an atom, typically an electron is stripped away or dislodged from the shell of the atom. This changes the properties of the atom – leaving it with a net positive charge. Note that the high energy level of ionizing radiation is basic to its nature, and distinct from what its *intensity* may be in any given instance.

Ionizing radiation is generally harmful and potentially lethal because it can alter the molecules in living organisms, such as the genetic material of cells. If the genetic material of a cell is altered, it may lead to death of the cell or to cell mutation.

Ionizing radiation can come from outer space or from naturally occurring materials in the terrestrial environment, such as uranium or radon gas. Ionizing radiation can also be introduced into the environment from human activities like nuclear power production, medical and industrial uses, the transportation of radioactive material, mining, and by drilling for oil and gas. *Note that smart meters do not produce or use ionizing radiation.*

Non-Ionizing Radiation

In contrast, the waves of non-ionizing radiation inherently do not possess enough energy to displace electrons from the shell of an electron. Non-ionizing radiation may cause excitation of an electron, moving it to a higher energy state, but not stripping it away.

Electromagnetic radiation whose frequency is between that of extremely low frequency radiation and ultraviolet light is considered non-ionizing radiation. The radio emissions from cell phones, smart meters, and other forms of wireless communication lie between these two extremes. Therefore, radio communication from a smart meter is a form of non-ionizing radiation.

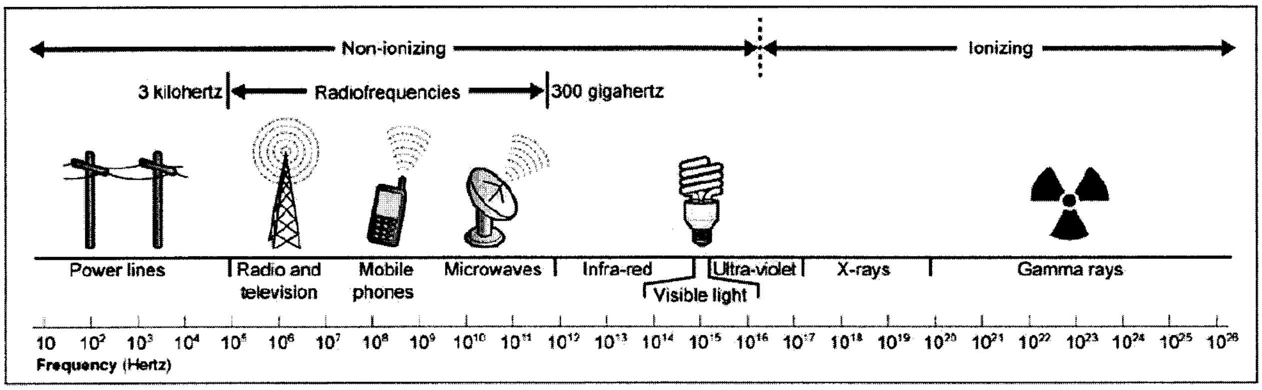
Electromagnetic Spectrum

The various forms of radiation, whether ionizing or non-ionizing, lie on a continuum called the electromagnetic spectrum, as seen in Figure 1. Smart meters that communicate wirelessly use frequencies that are between the frequencies of UHF television channels and those of mobile phones (somewhere between 900 MHz and 2.4 GHz), depending on the wireless technology (or technologies) the meters employ.

Figure 2 shows some of the chart's information in a tabular format. The frequency range in which wireless smart meters transmit data has been emphasized in that figure.

Note that the Public Utility Commission of Texas addressed potential health effects of extremely low frequency (60 Hz) electric power at very high voltages and currents, as is conducted in transmission lines. That report, issued in 1992, was entitled "Executive Summary: Health Effects of Exposure to Powerline-Frequency Electric and Magnetic Fields." The considerations being addressed in this *Health and RF EMF from Smart Meters* report are substantially different from those contemplated in 1992.

Figure 1: Chart of the Electromagnetic Spectrum[4]



[4] Not shown in the chart is the fact that as the frequency (Hz) of radiation increases, the "electron volt" (eV) value increases in a linear fashion. In this context, electron volts serve as a measure of how much energy the radiation carries and therefore the potential it has to excite an electron (or, if it has enough energy, dislodge it from an atom).

Figure 2: Types of Radiation and Their Frequency Ranges

Frequency Range	Top End of Frequency Range (in Hz)	Designation or Abbreviation	Primary Use
Radio. Non-ionizing radiation.			
3 – 30 Hz	30	ELF	Submarine communications
30 – 300 Hz	300	SLF	Not commonly used; electrical power is in this range
300 – 3000 Hz	3,000	ULF	Military communications
3 – 30 kHz	30,000	VLF	Submarine communication
30 – 300 kHz	300,000	LF	Military, AM radio
300 kHz – 3 MHz	3 million	MF	AM radio, shortwave radio
3 – 30 MHz	30 million	HF	Amateur radio, CB radio, aviation radio
30 – 300 MHz	300 million	VHF	VHF TV, FM radio, amateur radio
300 MHz – 3 GHz	***3 billion***	***UHF "microwave"***	***UHF TV, land-based mobile radio, cell phones, smart meters***
3 – 30 GHz	30 billion	SHF "microwave"	WLAN, radars, industrial devices
30 – 300 GHz	300 billion	EHF "microwave"	Short range data transmission
Light. Non-ionizing radiation.			
300 GHz – 400 THz	400 trillion	Infrared (IR)	TV remote controls, heat lamps
400 THz – 770 THz	770 trillion	Visible ("light")	Illumination
Ionizing radiation.			
750 THz – 30 PHz	30 quadrillion	Ultraviolet (UV)	Tanning beds, medical, industrial applications
30 PHz – 30 EHz	30 quintillion	X-Ray	Medicine, scientific, and industrial uses
more than 15 EHz	> 15 quintillion	Gamma ray	Medicine, scientific, and industrial uses

Electromagnetic Fields

An electromagnetic field is the result of the mutual interaction of electric and magnetic fields.[5] An electric field can be most simply described as being produced by stationary charges. A higher voltage yields a stronger electric field. In contrast, a magnetic field is produced by moving charges (typically electrons, i.e., an electric current). A greater current flow yields a stronger magnetic field.

An RF electromagnetic field is an electromagnetic field that is produced by electrical current that is oscillating at a radio frequency, which is defined as a frequency between 3 cycles per second and 300 billion cycles per second. Smart meters typically communicate with one another (or to their data concentrator) in a frequency band that is near 900 MHz.

Electromagnetic (EM) field intensity decreases greatly with distance. There are many variables involved in precisely calculating the anticipated intensity of an EM field from a given distance. To simplify the mathematics involved, it can be reasonably stated that the intensity of an EM wave, which is three-

[5] <http://www.britannica.com/EBchecked/topic/183201/electromagnetic-field>.

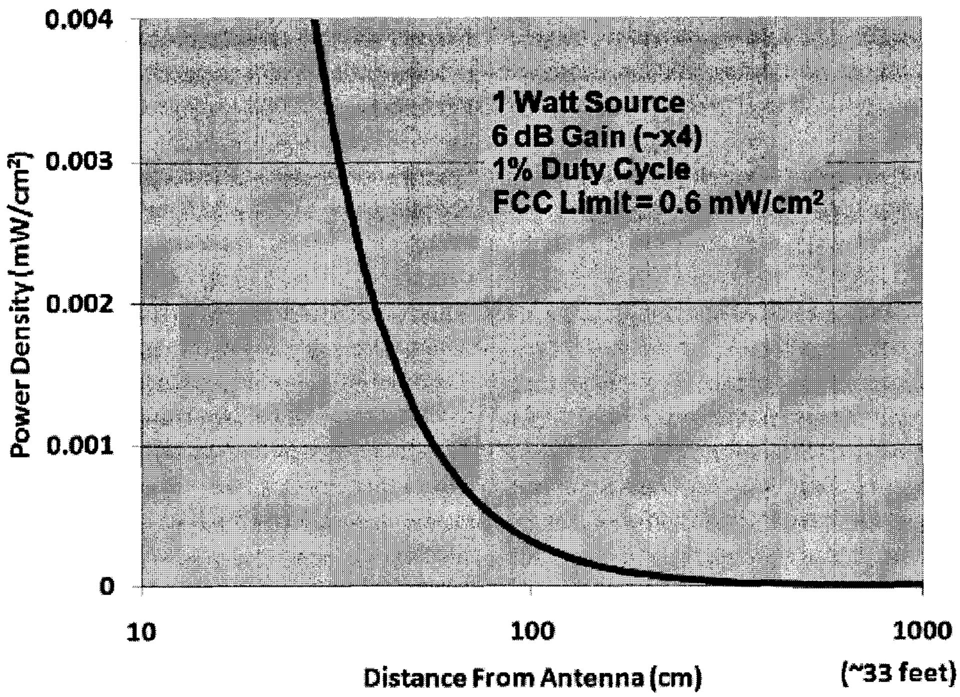
dimensional, decreases exponentially at a rate of approximately the square of the distance from its source. This is known as the inverse-square law,[6] expressed as a mathematical formula by:

$$Y = \frac{1}{X^2} \text{ (where } Y \text{ is the intensity and } X \text{ is relative distance).}$$

For example, if the EM intensity from a smart meter is measured to be Y_0 at an initial distance of 1 foot away, then Y_1, the field intensity from two feet away, would be $(\frac{1}{2^2})Y_0$, or $\frac{1}{4}Y_0$. From a three-foot distance, the intensity Y_2 will be $(\frac{1}{3^2})Y_0$, or $\frac{1}{9}Y_0$. From ten feet away, the field intensity will only be $(\frac{1}{10^2})Y_0$, or 1/100th of what it was at one foot away. Figure 3 shows how the average power density of EMF from a typical smart meter varies with distance.

Upon inspecting the graph, the power density value may appear to become zero, but in actuality it does not; the resolution of the image belies the asymptotic nature of the curve. While the power density may seem to become infinitesimal at the greater distances shown, the radio circuitry of smart meters is sensitive enough to receive and process the signal.

Figure 3: Calculated Average Power Density vs. Distance for a Typical Smart Meter[7]



[6] <http://www.osha.gov/SLTC/radiofrequencyradiation/electromagnetic_fieldmemo/electromagnetic.html#appendix_b>.
[7] Notes: The graph shows expected (calculated) values. The power density is average power density, not instantaneous; measured values will vary around a nominal value. This graph does not account for possible ground reflections, but ground reflections would not change the basic shape of the curve. Graph source: EPRI.

EMF and RF EMF in our Environment

Almost all household devices powered by electricity emit RF EMF in some amount. The FCC has classified devices in three categories – intentional radiators, unintentional radiators, and incidental radiators.

- Intentional radiators deliberately generate and emit RF energy. Typical intentional radiators include cordless telephones, remote control toys, garage door openers, mobile data devices such as iPads, and other low power transmitters.

- Unintentional radiators are devices that generate and use RF energy within the device but are not intended to emit RF energy. Typical unintentional radiators include devices such as personal computers, printers, automobile dashboard electronics, and other digital devices that have internal "clocks" or circuitry used for timing within the device. Radio receivers, such as television receivers and AM/FM radios, are also unintentional radiators.

- Incidental radiators are devices that generate RF energy during the course of their operation but are not intentionally designed to generate or emit that energy. Typical incidental radiators include automobile ignition systems, ceiling fans, vacuum cleaners, electric shavers, and mechanical light switches.

RF EMF also comes from natural sources, such as the sun, the Earth, and the outer layer of the Earth's atmosphere (the ionosphere).

The environment in which we live includes numerous other sources of RF EMF sourced from outside the home. These sources are intentionally transmitted and beyond an individual's control. The transmitting sources emit RF at a much greater intensity than smart meters do, and the signals permeate homes and other buildings. This RF EMF has had a ubiquitous presence both indoors and outdoors since the 1920s when AM radio broadcasts (centered near the 1 MHz frequency) were introduced. In the 1930s, FM radio (around 100 MHz) was introduced, and then in the 1940s and 1950s, the broadcasting of VHF television (50 to 200 MHz) and UHF television (400 to 900 MHz) expanded. Satellite communication started in the 1960s and is now commonplace, including for consumer use. Cellular telephone towers (base stations) have been deployed in increasing numbers since at least the 1990s; they are now considered ubiquitous.

Other sources of RF EMF one may encounter in public and private places are wireless routers, cordless telephones, cellular phones, RF remote control devices, and baby monitors. The intensity of EMF emitted by each of these devices is documented to be well below the threshold that requires any type of notification signage.[8]

The Role of RF EMF in our Country's Infrastructure

The United States of America (U.S.) has had a wireless communications infrastructure in place for nearly a hundred years. For example, radio and television stations have continually broadcasted their programming in all directions for public consumption since the early part of last century. Emergency services like police, fire, and ambulance services have their own dedicated radio spectrum. Municipal governments and the military also transmit data on various frequency bands assigned to them. Citizen's Band and short wave radio are used by individuals and hobbyists, but one could argue that it is also a part of our nation's communications infrastructure that benefits all, especially in times of emergency.

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[8] <http://standards.ieee.org/findstds/standard/C95.2-1999.html>.

Satellite transmissions blanket our country from above, using various frequencies in the RF band. Downlinks from satellites are used by the television and radio industries for delivery of syndicated programming to local stations. Satellites also provide Internet access to users in remote areas and television programming for those without access to cable television or who seek an alternative. They also provide subscription-based programming for SiriusXM radio, and to fulfill government functions such as transmitting climate and mapping data and Global Positioning System (GPS) locational and timing information (which is used by utilities). The military also uses satellites for communications and surveillance.

Cell phones and their associated base stations are also a common source of EMF, having become ubiquitous worldwide; the International Telecommunication Union reported that there were six billion mobile phone subscriptions by the end of 2011, nearly one for every human being on the planet.[9]

Some people object to the installation of wireless smart meters on the grounds that they fear exposure to RF and because they do not anticipate benefitting from the devices' advanced capabilities. What they may not realize or acknowledge is that every individual is continuously exposed to RF emitted by a multitude of local television (TV) and radio stations, irrespective of whether one ever chooses to tune into any of them.

When a new radio or TV station begins broadcasting in a community, it introduces a new source of RF to a wide area. While the *exposure* to RF emissions is the primary consideration for the topic of this paper, some opponents of smart meters have called attention to their power output. It is therefore worth noting that the permitted maximum effective radiated power (ERP, which includes antenna gain[10]) of an FM radio station transmitter in the U.S., depending upon its FCC classification, can be as high as 100,000 watts.[11] In contrast, the radio module in a wireless smart meter is only capable of a maximum power output of one watt, and in some implementations, it is even less than that. The ERP of a stationary cell phone base station is limited to either 500 or 1000 watts, depending on its location.[12] The maximum peak ERP of a cell phone in the U.S., for example one operating in the GSM-1900 band and at GSM Power Class Number 30, is two watts.[13]

Despite the fact that radio stations broadcast at power levels that are tens of thousands times higher than those of smart meters, Staff could not find any references to reported health complaints or individuals attributing their health issues to new radio or TV transmissions. Similarly, while a limited number of people may still have some trepidation regarding cellphone towers, their ubiquity and the continued popularity of cell phones and other wireless communication devices seems to have quelled the number of concerns being expressed.

Advanced Metering Infrastructure

Making prudent investments in RF communications technologies has become essential to maintaining our quality of life, and many aspects of the world's infrastructure depend upon it. Many industries, including electrical utilities, use radio communication as an essential tool. Until recently, utilities have traditionally limited their use of radio to telemetry, transmitting system data from distant points along the transmission portion of the electric grid.

[9] <http://www.itu.int/net/pressoffice/press_releases/2012/70.aspx>.
[10] In this context, this is defined by how well a transmitting antenna converts input power into radio waves headed in a specified direction.
[11] <http://www.fcc.gov/encyclopedia/fm-broadcast-station-classes-and-service-contours>.
[12] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol2/xml/CFR-2011-title47-vol2-sec22-913.xml>.
[13] <http://www.radio-electronics.com/info/cellulartelecomms/gsm_technical/power-control-classes-amplifier.php>.

Now many of the electric utilities in the U.S. are enhancing the distribution portion of the electrical infrastructure by modernizing its technology. One of the ways electrical utilities are upgrading distribution grid technology is by replacing existing electric meters with Advanced Metering Infrastructure (AMI). The meters being replaced typically have an analog display[14] in the form of a series of dials that indicate accumulated usage and a large spinning aluminum disk that protrudes through the face of the meter. This electromechanical technology is over a century old and has shortcomings.

The most important feature of the meters used in AMI ("smart meters") is that they measure and record usage data in regular intervals[15] and allow for two-way communications between the utility and the customer. These smart meters and their associated communication components form an infrastructure that allow utilities to overcome the old technology's limitations and is now crucial to the utility and to the energy market's proper functioning.

Almost all smart meters used in the U.S. communicate by means of wireless technology. Each utility proposes the technology it will deploy and determines how it is to be configured in order to best suit the needs of its service area. The most common method of communication chosen by Texas utilities has been in the form of a wireless mesh network.

A wireless mesh network topology allows "mesh-enabled" meters to securely route data via other nearby meters and relay devices. These meters and relay devices are connected to several other mesh-enabled devices. All these devices function as signal repeaters and relay the data to an access point. The access point device aggregates, encrypts, and conveys the data to and from the utility (this is known as the backhaul portion of the network). The access point typically uses cellular phone technology to transport this data.[16]

Wireless Technology Standards and Regulation

Intentional radiator devices such as cordless telephones, cellular phone handsets, and smart meters operate in unlicensed spectrum. Unlicensed spectrum is simply a band that has pre-defined rules for both the hardware and the deployment methods of the transmitting radio; they are required to be tested and certified as compliant with these rules before they can be marketed. Financial penalties can be assessed if one does not comply with the appropriate Federal Communications Commission (FCC) equipment authorization procedure.[17] The mitigation of potential interference within the bands is addressed by the FCC definition of technical rules rather than the agency restricting the bands by issuing an exclusive license to use the spectrum.[18,19]

Any person or entity that complies with the rules for the equipment (which are pre-certified by the manufacturer) and its use can establish a license-free network at any time for either private or public purposes. This is why a person can set up a wireless network at home and a utility can set up its smart meter mesh network without having to obtain a license from the FCC. The radio(s) in the smart meter is pre-certified, just as a home user's wireless router is.

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[14] Note that not all meters being replaced have the same appearance. A few of the old meters may have digital displays and solid state circuitry, but are not considered to be AMI.
[15] Due to the limited scope of this paper, the specific market and regulatory aspects of Texas and the ERCOT market and the infrastructure design choices of each of the utilities will not be discussed.
[16] There are several possible variations to the mesh design described above. Take what is outlined here as an example.
[17] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet63/oet63rev.pdf>.
[18] <http://www.wimax.com/wimax-regulatory/what-is-unlicensed-spectrum-what-frequencies-are-they-in>.
[19] U.S. frequency allocations: <http://www.ntia.doc.gov/files/ntia/publications/spectrum_wall_chart_aug2011.pdf>.

The FCC is required by the National Environmental Policy Act of 1969 to evaluate the effect of emissions from FCC-regulated transmitters on the quality of the human environment. At the present time there is no federally-mandated RF exposure standard. However, several non-government organizations, such as the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers (IEEE), and the National Council on Radiation Protection and Measurements (NCRP) have issued recommendations for human exposure to RF electromagnetic fields.[20] The potential hazards associated with RF electromagnetic fields are discussed in the FCC's Office of Engineering and Technologies (OET) Bulletin No. 56, "Questions and Answers About Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields."[21]

On August 1, 1996, the FCC adopted the NCRP's recommended MPE limits for field strength and power density for the transmitters operating at frequencies of 300 kHz to 100 GHz. In addition, the FCC adopted the Specific Absorption Rate (SAR) limits for devices operating within close proximity to the body as specified within the ANSI/IEEE C95.1-1992 guidelines.[22] The FCC's requirements are detailed in Parts 1 and 2 of the FCC's Rules and Regulations [47 C.F.R. 1.1307(b), 1.1310, 2.1091, 2.1093].[23,24,25,26]

Studies by EPRI and others have found that the exposure an individual would receive from a smart meter that is 10 feet away is not much different from the range of exposure levels received from TV and radio broadcasts.

The Effects of RF EMF on Living Tissue

There are three scientifically established mechanisms where EMF is known to cause health effects:[27,28]

- Induced voltage gradients and/or electric currents in the body;
- Thermal effects (dielectric heating); and
- Ionizing radiation effects.

The relative importance of these mechanisms depends on the EMF frequency and field strength. Decades of research into EMF and health has produced a large body of scientific literature which national and international standards organizations have reviewed to establish their safe exposure limits. For example, the WHO has formally recognized the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to develop its international EMF exposure guidelines.

At frequencies in the range of 0-3 kHz, induced voltage gradients and/or electric currents in the body are the only known health effects in the presence of strong electric and magnetic fields. Because the purpose of this report is to address smart meters that communicate using RF, induced voltages and currents will not be discussed. Smart meters do not emit ionizing radiation, so that topic will also not be covered in this document. If one would like to know more about the health effects of induced voltages or ionizing radiation, credible resources are freely available elsewhere.

[20] <http://transition.fcc.gov/oet/rfsafety/background.html>.
[21] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf>.
[22] <http://standards.ieee.org/findstds/standard/C95.1-2005.html>.
[23] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol1/xml/CFR-2011-title47-vol1-sec1-1307.xml>.
[24] <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol1/xml/CFR-2011-title47-vol1-sec1-1310.xml>.
[25] <http://www.gpo.gov/fdsys/pkg/CFR-2009-title47-vol1/xml/CFR-2009-title47-vol1-sec2-1091.xml>.
[26] <http://www.gpo.gov/fdsys/pkg/CFR-2009-title47-vol1/xml/CFR-2009-title47-vol1-sec2-1093.xml>.
[27] <http://www.emfandhealth.com/EMFExplained.html>.
[28] <http://standards.ieee.org/findstds/standard/C95.6-2002.html>.

Thermal effects are the primary health impact when living tissue absorbs enough EMF power to cause heating. This effect is the primary concern in the RF frequency range of 30 MHz to 300 GHz. In theory, the total EMF power absorbed by tissue is determined by the photon energy multiplied by the number of photons per second being absorbed. The practical method used to measure this energy is based on the SAR. For portable devices, the FCC specifies that SAR safety limits are to be used.[29] These safety limits are specified in units of watts per kilogram (W/kg) of body tissue.

Note that the energy from devices that are not intended for use within 20 centimeters of a user, such as smart meters, is measured using a different methodology. The FCC safety limits for these devices, known as Maximum Permissible Exposure (MPE), are specified in units of microwatts per square centimeter ($\mu W/cm^2$).

Existing regulations from the FCC set the SAR and MPE safety limits in the U.S. Other countries such as the United Kingdom (UK), Canada, and Australia have similar standards. International standards regarding safety for commercial products also exist from entities such as the WHO and the ICNIRP and are also similar to the U.S. standards.

The Scientific Method, the Value of Meta-analysis, Laymen Difficulties, and other Cautions

The investigation of RF EMF and its potential effects on health requires an understanding of several fields of science. While the intent of this report is not to impart a deep understanding of all the relevant scientific fields of study, it is still important to have a basic grasp on the concepts and what science itself entails. The latter is referred to as the scientific method.

Meta-analysis is an important tool in science because in some areas of study there are a large number of studies which are similar, and researchers want to have a method of combining them to help facilitate drawing satisfactory conclusions.

People generally have an interest in maintaining their health, so any given research study that shows a positive correlation between a disease and an environmental factor will naturally have the tendency to pique the interest of the public more than one that does not show any correlation. While journalists and news editors have codes of ethics and guidelines for professional conduct,[30,31,32,33] there is a risk that the mass media may sensationalize an individual study which shows such a correlation and be less inclined to report research studies that refute the findings, because documenting something which may be interpreted by an audience as uneventful is not as captivating or lucrative. Studies have revealed that the publishing of misconceptions about alleged effects of exposure to electric or magnetic fields in the popular press is not uncommon.[34,35,36,37] Some less reputable media outlets may be motivated by viewership ratings, subscription renewals, or webpage hits, rather than reporting the news properly. Integrity in the media plays a role in maintaining the integrity of scientific research.

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[29] The FCC defines portable devices as transmitters whose radiating structures are designed to be used within 20 centimeters (approximately eight inches) of the body of the user.
[30] <http://www.rtdna.org/pages/media_items/code-of-ethics-and-professional-conduct48.php?g=36?id=48>.
[31] <http://www.apme.com/?page=EthicsStatement>.
[32] <http://asne.org/content.asp?pl=24&sl=171&contentid=171>.
[33] <http://www.spj.org/ethicscode.asp>.
[34] <http://www.dtic.mil/dtic/tr/fulltext/u2/a275434.pdf>.
[35] <http://www.jmpee.org/JMPEE_PDFs/26-4_bl/JMPEE-Vol26-Pg189-Jauchem.pdf>.
[36] <http://www.jmpee.org/JMPEE_PDFs/28-3_bl/JMPEE-Vol28-3-Pg140-Jauchem.pdf>.
[37] <http://www.jmpee.org/JMPEE_PDFs/30-3_bl/JMPEE-Vol30-Pg165-Jauchem.pdf>.

Understanding the concepts behind science is important because opponents of wireless data transmission technologies have attempted to use science (typically by quoting research studies) as support for their arguments. At the same time, one must remain mindful of the relationships among science, modern media, and the public.

Scientific Method

The modern use of the word "science" is defined both as a reliable body of knowledge that can be logically and rationally explained and also by the method of pursuing that knowledge, namely, the scientific method. Scientific method requires inquiry to be based on evidence that is empirical and measurable and is subject to specific principles of reasoning. More specifically, the scientific method consists of systematic observation, measurement, and experiment, as well as the formulation, testing, and modification of hypotheses.[38]

The following process steps[39] are considered the basic elements of scientific method:

- Formulate a question - to summon an explanation of a specific observation, or it can be open-ended;
- Hypothesis - a conjecture that may explain the observed behavior;
- Prediction - made by determining the logical consequences of the hypothesis;
- Test - investigate (via experiment) whether the real world behaves as predicted by the hypothesis; and
- Analysis - determine what the experimental results demonstrate and decide the next actions to take.

Other components are necessary to the scientific process, even when all the iterations of the steps above have been completed:

- Replication - if an experiment is repeated and does not produce the same results, this implies that the original results were in error. As a result, it is common for a single experiment to be performed multiple times, especially when there are uncontrolled variables or other indications of experimental error. Surprising or significant results may motivate other scientists to also investigate, especially if the results would be important to their own work;
- External review - experts perform a peer review, which is an evaluation of the experiment. These experts give their opinions anonymously to foster unbiased criticism. The peer review does not certify correctness of the results, only that the experiments themselves were sound. Note that the evaluation of the experiment depends on its description being supplied by the experimenter. If the work passes peer review (which may require new experiments requested by the reviewers), it will be published in a peer-reviewed scientific journal. The journal that publishes the results indicates the perceived quality of the work; and
- Data recording and sharing - scientists must record all data very precisely to reduce their own bias and aid in replication by others. This data must be supplied to other scientists who wish to replicate any results. Experimental samples that may be difficult to obtain must also be shared.

Scientific studies are intended to be as objective as possible to reduce any bias in how the results are interpreted. All data and the methodologies employed are to be documented, archived, and shared so that they are available for close scrutiny by other researchers. This gives scientists the opportunity to verify results by attempting to reproduce them and establish statistical measures of the reliability of the experimental data.

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[38] <http://oxforddictionaries.com/definition/english/scientific%2Bmethod>.
[39] <http://en.wikipedia.org/wiki/Scientific_method>.

Meta-analysis

The study of EMF has been going on for decades resulting in a multitude of research studies, many of which possess similar elements. The existence of such large bodies of work makes researchers want to integrate similar studies and attempt to synthesize more definitive conclusions. The traditional method of integration calls for a reviewer to provide a narrative, namely a chronological discourse on previous findings.[40] Gene V. Glass, the statistician and researcher who coined the term meta-analysis, considered the traditional method to be flawed and inexact because reviewers:

- Are unable to deal with the large number of studies on a topic and focus on a small subset of studies, often without describing how the subset was selected;
- Often cite the conclusions of previous reviews without examining those reviews critically; and
- Are usually active and prominent in the field under review. Therefore, they might not be inclined to give full weight to evidence that is contrary to their own positions.

In a meta-analysis, research studies are collected, coded, and interpreted using statistical methods similar to those used in primary data analysis. The result is an integrated review of findings that is more objective and exact than a narrative review.

Inherent Problems and Laymen Difficulties with Scientific Research; Non-traditional Medicine

Science is by no means a discipline of perfection; it depends upon human thought and activity, and is thereby subject to human failings, including the introduction of bias into the process steps outlined above. Most failures can be attributed to inadvertent errors, while some failures can be pinned on researchers that have taken shortcuts through the scientific process. Only rarely have researchers who had been generally considered to be legitimate been found attempting to subvert science for personal benefit, to perhaps gain notoriety, or to secure future research grants.[41]

Findings of scientific misconduct occasionally come to light. In the course of gathering material for this paper, Staff discovered several studies of RF EMF and health that were found to be fraudulent. For example, the U.S. Department of Health and Human Services' (HHS) Office of Research Integrity found that Robert P. Liburdy, Ph.D. engaged in scientific misconduct in biomedical research by intentionally falsifying and fabricating data and claims about the purported cellular effects of EMF that were reported in two of his scientific papers.[42] Another example of misconduct was exposed through an investigation performed by an independent review body at the Medical University of Vienna. The investigation revealed that data was fabricated in two papers authored by lab chief Hugo Rüdiger and his colleagues in 2005 and 2008 which reported DNA breakage in cells exposed to electromagnetic fields. The papers were part of a European Union-funded project called REFLEX.[43]

Some people have made assertions that research studies that had depended upon funding or other support from industry should be considered as unreliable and having tainted results. What is far more important than the sources of funding for research is strict adherence to the scientific process. Rigorous peer reviews, combined with attempts by others to replicate results, tend to remove from consideration studies whose results rely on questionable research practices. Opponents of wireless technology may not understand this, and have expressed dismay when content from studies they favor does not appear in other documents such as

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[40] <http://echo.edres.org:8080/meta>.
[41] <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0005738>.
[42] <http://grants.nih.gov/grants/guide/notice-files/not99-111.html>.
[43] <http://www.emfandhealth.com/sciencerudigerfraud.pdf>.

the report by the California Council on Science and Technology.[44] There is a risk that opponents may attribute the exclusion of favored material to attempts by government agencies or industry to suppress the truth rather than accepting the idea that the opponents' favored studies were errant or lacked scientific rigor.

Nonetheless, some research studies can receive undeserved notoriety despite shortcomings such as:

- Experiments that are poorly designed or lack sufficient controls;
- Studies that are inadequately peer-reviewed;
- Public revelation of findings that are only preliminary;
- Reports that are unpublished but appear in the popular press;
- Reports published in scientific journals of lesser esteem;
- Conclusions that are drawn to satisfy a political agenda rather than advance human knowledge; and
- Cited primary research studies are old and out of date.

The "BioInitiative Report"[45] is an example of a report that received notoriety despite being viewed negatively by the research community. Its contributors are described as a group of 14 scientists, researchers, and public health policy professionals. The stated purpose of the report was to document "bioeffects, adverse health effects and public health conclusions about impacts of non-ionizing radiation." The document was edited by Cindy Sage, an environmental consultant, and Dr. David O. Carpenter, director of the Institute for Health and the Environment at the State University at Albany (New York).

The report is often cited by opponents of wireless technology, but it was widely criticized by government research agencies and subject matter experts in Australia,[46] Belgium,[47] the European Commission (EC),[48] France,[49] Germany,[50] and the Netherlands.[51] It was also criticized by EPRI[52] and the IEEE.[53] The overall opinion of these institutions was that the report had many shortcomings. Some of the stated criticisms were that the report:

- Provided views that were not consistent with the consensus of science;
- Recommended safety limits that were not supported by the weight of scientific evidence;
- Included selection bias in several research areas;
- Lacked objectivity and balance; and
- Suffered from uneven editing quality.

Some researchers have developed a level of notoriety for their assertions regarding the purported dangers of EMF exposure. Opponents of wireless technology have naturally called upon these people to testify as expert witnesses and this tends to raise their profiles to an even greater degree. These efforts have not always been successful. For example, Carpenter attempted to rely on his work on the BioInitiative Report as one of the qualifications to testify as an expert for intervenors opposed to plans by Hydro Québec, a utility in Canada, to

44 <http://www.ccst.us/publications/2011/2011smart-final.pdf>.
45 <http://www.bioinitiative.org/freeaccess/report/docs/report.pdf>.
46 <http://www.acrbr.org.au/FAQ/ACRBR%20Bioinitiative%20Report%2018%20Dec%202008.pdf>.
47 <http://mmfai.info/public/docs/eng/MMF_Viewpoint_BioInitiativeReport.pdf>.
48 <http://ihcp.jrc.ec.europa.eu/our_activities/public-health/exposure_health_impact_met/emf-net/docs/efrtdocuments/EMF-NET%20Comments%20on%20the%20BioInitiative%20Report%2030OCT2007.pdf>.
49 <http://www.afsset.fr/upload/bibliotheque/964737982279214719846901993881/Rapport_RF_20_151009_l.pdf>.
50 <http://www.emf-forschungsprogramm.de/int_forschung/wirk_mensch_tier/Synopse_EMFStudien_2008.pdf>.
51 <http://www.gezondheidsraad.nl/sites/default/files/200817E_0.pdf>.
52 <http://emf.epri.com/BioInitiative_Working_Group_Report_Updated_7-09.pdf>.
53 <http://www.emfandhealth.com/12265_COMAR_2009.pdf>.

install wireless smart meters on homes and businesses. The regulatory authority for the province, The Québec Energy Board (The Board), stated (translated from French):[54]

> "The Board has refused to grant the requested expert status on the grounds that David Carpenter is not a doctor, never had clinical experience with patients and has never personally done any research on the effects of RF health.[55] The Board does not, however, reject his testimony in the case because of his knowledge on the research done by others in this field. It therefore accepted this testimony, subject to establishing the probative value to be accorded."

The Board also did not view Carpenter as independent and unbiased, as required by its rules governing the expectations of expert witnesses. The Board stated (translated from French):[56]

> "Clearly, the witness Carpenter, expert or not, does not meet the criteria of objectivity which the Board is entitled to expect."

Another individual who has been described as an expert by opponents of wireless technology is Magda Havas, a professor at Trent University, a liberal arts institution located in Peterborough, Ontario, Canada. Havas is not a medical doctor; she has a B.S. degree in biology and a Ph.D. in botany (the study of plant life).[57]

While not naming Havas directly, in response to her assertions against the proposed installation of Wi-Fi in several schools in Canada and the U.S., her colleagues at Trent University published a brief statement[58] in the *Peterborough Examiner* newspaper:

> On the issue of health effects of radio frequency waves, a large body of evidence now exists, and the international consensus is described in the references listed at www.trentu.ca/physics/emfrefs.pdf. Based on these considerations, we do not believe that electromagnetic waves associated with Wi-Fi in schools pose a health risk to children or teachers.
>
> Profs Bill Atkinson, Peter Dawson, David Patton, Ralph Shiell, Alan Slavin and Rachel Wortis
> Members of the Department of Physics, Trent University

Havas' critics are not limited to her colleagues at Trent. There are a few websites whose stated goals are to enhance the public's familiarity with sound scientific concepts. These sites state that their contributors seek to promote a better understanding of science and to help others distinguish between evidence-based science and poor science. Some contributors have responded to Havas' activities by creating pages that are dedicated to exposing and explaining what they claim to be significant flaws in her studies, contradictory statements she has made, comments which were not consistent with established facts, and instances where they claim she had misled the public.[59,60,61,62,63,64,65]

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54 <http://internet.regie-energie.qc.ca/Depot/Projets/111/Documents/R-3770-2011-A-0163-DEC-DEC-2012_10_05.pdf>.
55 David O. Carpenter holds a medical degree (M.D.) from Harvard but is not accredited to practice medicine.
56 <http://www.regie-energie.qc.ca/regie/DirectivesInstructions/Regie_RoleExperts_18juillet2011.pdf>.
57 <http://www.magdahavas.org/dr-magda-havas-bio/>.
58 <http://www.thepeterboroughexaminer.com/2010/10/15/physicists-see-no-danger-from-wifi-in-schools>.
59 <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%201.html>.
60 <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%202.html>.
61 <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%203.html>.
62 <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%204.html>.
63 <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%205.html>.
64 <http://www.emfandhealth.com/EMF&Health%20EHS%20Poor%20Studies%206.html>.

Note that some of the work that Havas performs involves the study of Electromagnetic Hypersensitivity (EHS), which has not been recognized by the medical or scientific communities as a valid diagnosis.

Some scientists and medical practitioners may be valued as experts by a small segment of the population because their ideas have been proclaimed as novel or superior because they do not conform to the prevailing conclusions of the scientific or medical communities. These researchers and medical professionals may be characterized as fighting the medical or scientific establishments for the benefit of their supporters. The problem is if these maverick researchers become imbued with noble stature because of these impressions, it may put the integrity of true science and medicine at risk.

Scientists prefer to maintain cordial relationships with one another and therefore avoid using the terms "junk science" and "pseudoscience" when referring to research or unconventional medical treatments they find questionable, because these terms are considered pejorative.

While skepticism of research is central to ensuring its quality, it is important to avoid being drawn to the allure of ideas that conflict with the body of scientific evidence. Without an appreciation for the meaning and value of scientific consensus, one risks being distracted by notions that have been discounted by numerous studies conducted in adherence to the scientific method.

Scientific consensus can be described as the collective judgment, position, and opinion of the community of scientists in a particular field of study.[66] In the context of scientific research, consensus is general agreement and not unanimity, which has a stricter meaning. This collective judgment of scientists cannot be used as a valid scientific argument on its own, and that it is not part of the scientific method; it is more the *result* of it.

A consensus can be developed by scientists through replication of experimental results, peer review, and publication of results – key components of the scientific method. When this process is followed iteratively and agreement exists, those within the discipline recognize they have reached a consensus. As scientific research continues and new data is produced by experiment, models are refined. This change may bring about shifts in scientific consensus. How consensus within the scientific community develops over time is a study in its own right.[67]

The challenge for researchers becomes communicating to outsiders (especially laymen) that scientific consensus has been reached. This is because to the uninitiated, the debates through which science progresses may seem to be contestation. Laypeople and others outside the particular field of study who misinterpret these scientific debates as adversarial may reach erroneous conclusions about the science. When scientific debate is misinterpreted in this manner, effective government also may be subject to risk. The risk is that members of the public that have misconceptions about the existence of scientific consensus may exert pressure on their elected leaders to devise public policy that is based on faulty assumptions.

In medicine, one result of misinterpreting scientific debate can be a mistaken belief in a medical diagnosis that the scientific community does not recognize as valid, such as EHS. If the true cause of an affliction is not diagnosed, it can lead to negative consequences for an individual. Medical professionals and others may offer treatments that are not efficacious or have not been properly vetted for safety. The pursuit of these treatments can delay receiving effective medical care.

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[65] <http://www.sciencebasedmedicine.org/index.php/cfls-dirty-electricity-and-bad-science/>.
[66] <http://en.wikipedia.org/wiki/Scientific_consensus>.
[67] <http://asr.sagepub.com/content/75/6/817.full.pdf+html>.

The Internet offers amulets made of crystal or stone, typically worn as a pendant around the neck, that are purported to help an individual overcome EHS or to mitigate the claimed negative health effects of exposure to EMF. No valid scientific explanations are offered to explain the mechanisms by which these items may operate. Dietary supplements are promoted with claims they provide a "strong protective effect" against EMF but have not been assessed by the U.S. Food and Drug Administration (FDA) for safety or effectiveness.

Some physicians offer treatments for EHS and other purported "environmental sensitivities." One such doctor is Dr. William J. Rea of Dallas, Texas. An example treatment by Rea is that he will administer injections of a highly diluted solution of automobile exhaust to provide an "electromagnetic imprint" of the environmental pollutant. Rea claims that a patient's immune system will interact with the injections and desensitize the patient to the substance.

Staff has not been able to locate any other references to the term "electromagnetic imprint" in a medical context.

Rea's treatments had met with controversy, leading the Texas Medical Board to file a complaint against him[68,69,70] that resulted in a Mediated Agreed Order issued in 2010, requiring his consent form to state:

- The injections given are not FDA-approved;
- The patient will be receiving non-traditional medicine (must be in bold and oversized print);
- The effectiveness of the injections is disputed;
- There has been no testing of the contents of the injection or any proven medical effectiveness;
- The therapeutic value of the injections is not established or proven;
- There is no active agent in the therapy being provided; and
- The injections are not endorsed, sanctioned, or approved by the Texas Medical Board.

Rea's controversial treatments were also featured on a segment of ABC News' *Nightline* television program in 2008.[71,72]

Rea appeared before the Texas Senate Committee on Business and Commerce on October 9, 2012 to speak as a medical expert in opposition to wireless smart meters.

Cautions about Anecdotes, Attempts at "Do-it-Yourself" Science, and Reliance on Social Media and Blogs

Opponents of smart meters have provided accounts of ill health or have cited anecdotal reports of health problems that have been attributed by laypeople to the installation of smart meters. Caution must be used when considering anecdotal reports, because they:

- Are prone to human cognitive biases such as confirmation bias;[73]
- Use nonprobability sampling and therefore suffer from self-selection bias;[74]

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[68] <http://www.casewatch.org/board/med/rea/order.shtml>.
[69] <http://www.med.ohio.gov/pdf/Minutes/2011/08-11minutes.pdf>.
[70] <http://www.tmb.state.tx.us/news/press/2010/090210.php>.
[71] <http://abcnews.go.com/Nightline/video?id=5881281>.
[72] <http://www.youtube.com/watch?v=-gx4zxxi0xQ>.
[73] In psychology and cognitive science, confirmation bias is a tendency to search for or interpret information in a way that confirms one's preconceptions, leading to statistical errors. Source: <http://www.sciencedaily.com/articles/c/confirmation_bias.htm>.

- Do not supply a sufficiently large sample size;
- Prevent a rigorous statistical analysis of subject sample data;
- Do not account for a myriad of variables present in the environment (lack of controls); and
- Do not provide evidence that other aspects of the scientific method were followed.

In summary, conclusions drawn primarily from anecdotal reports do not possess scientific merit.

A common tendency for laypeople is to "cherry pick" scientific literature. Cherry picking is the act of pointing to data or individual cases that seem to confirm a particular position, while ignoring a significant portion of data or cases that may contradict the position. Selectively referencing only the studies that support a view is a common example of confirmation bias. Cherry picking may be committed unintentionally. Scientists are not immune to the behavior.

When raising concerns about wireless technology, some opponents have acquired RF EMF measurement equipment and posted online videos[75] showing readings being taken from smart meter installations. These videos have been presented as evidence that the smart meters were emitting RF EMF at levels higher than those claimed by utilities or meter manufacturers. More discerning viewers may question the validity of these videos for the following reasons:

- The videos tend to be brief, relying on fleeting numbers displayed on a readout;
- The data do not appear to be recorded for later study or shared with others;
- No evidence is provided that the operator is certified to use the measuring equipment;
- It is not noted whether the operator received any formal training to avoid, for example, using improper techniques when setting up or handling the equipment;
- Little explanation is offered to help the viewer determine if the appropriate settings were used (such as unit scaling) or whether instantaneous peak or average values were being measured;
- No evidence is given that the equipment was properly calibrated; and
- There may be other tools available which are better suited to the intended use.

One video[76] on YouTube that provides an example of an EMF measurement device being used purports to show the deleterious effects of a smart meter on a shrub situated directly in front of the meter in Stratford, Ontario, Canada. On the afflicted plant, the leaves have curled up and are losing color. There are two shrubs of identical breed on either side of it which do not seem to be as adversely affected. While a shrub is clearly not a human being, some smart meter opponents refer to the video as evidence of its apparent danger to all living things.

The person who recorded the video enabled the "audio analysis" mode on the measurement device, which creates a shrill sound reminiscent of a police siren but with varying pitch. The sound is intended to represent a characteristic signal pattern of the EMF being detected, which helps the device's user to identify the source of emissions. To an individual who has not experienced the operation of this device, the sound it makes in the presence of EMF may seem disturbing and evoke an unpleasant emotional response in the uninitiated.

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[74] Self-selection bias is a specific form of selection bias. Selection bias leads to distortions, because certain characteristics are over-represented in a sample. Self-selection bias introduces other errors. For example, sample populations that are the result of self-selection suffer from a correlation with willingness to be included. There may be a purposeful intent on the part of respondents.

[75] Go to YouTube: <http://www.youtube.com> and search for "smart meter emissions" or other similar phrases.

[76] <http://www.youtube.com/watch?v=lsuP_WBBr2c>.

An interesting observation about this video which some viewers may not notice is that as the camera focuses closely on the vegetation, it is readily apparent that the shrub is infested by what appears to be a large number whiteflies or aphids. These kinds of insects suck juices from the leaves of host plants, and can lead to serious injury, causing wilting, yellowing, leaf drop, and possibly death. As the video camera pans back and forth, one can see that the insects are also on the leaves of the adjacent shrubs, but are not yet as prevalent. The ability for viewers to provide comment is disabled for this particular video, so no one can call attention to the insect infestation or challenge the claims made by the person who posted the video.

The Texas A&M Forest Service estimated that 301 million trees had died across Texas forestlands as a result of the 2011 drought,[77] but to date there have been no known credible reports of dying vegetation attributed to smart meters or other wireless equipment despite the fact that millions of the devices have been deployed in the state.

Many smart meter opponents who have made assertions about the purported detrimental health effects of wireless technology have cited material obtained from blogs,[78] Internet videos, and other forms of social media as sources of information. Blogs may contain items that are topical but they are not to be confused with news sites; contributors to blogs are not held to standards for journalistic integrity. Most of the cited blogs are run by self-described activists who overtly state their opposition to smart meters and for various reasons. While blogs and social media sites have democratized the Internet, enabling almost anyone to widely publish his points of view, caution must be used when considering material obtained from such sources. These sites have many shortcomings, including the following:

- Site content is not vetted for objectivity or a diversity of opinions;
- Inaccurate reporting is common, and errors are rarely corrected;
- Many comments are written in an authoritative manner, promoting speculative statements as factual;
- Provocative language and hyperbole are often used to elicit emotional responses;
- Individuals promoted as experts tend to lack substantial academic credentials or possess credentials that are not associated with the field of study under consideration; and
- There is no assurance that authors resist the influence of advertisers or special interests.

The people who run blogs typically are not scientists and do not realize that an individual study is not to be considered definitive. Much of the research that Staff found cited on blogs was old and may have been out of date, or had been considered unreliable by the scientific community.

Case Law and Matters of Science

The Supreme Court cases *Daubert v. Merrell Dow Pharmaceuticals,*[79] *General Electric Co. v. Joiner,*[80] and *Kumho Tire Co. v. Carmichael*[81] articulated what is known as the "Daubert standard." The standard addressed Rule 702 of the Federal Rules of Evidence,[82,83] and clearly defined a judge's role in playing "gatekeeper," determining whether expert testimony is based on sound scientific reasoning and methodology.

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[77] <http://texasforestservice.tamu.edu/main/popup.aspx?id=16509>.
[78] A blog is a website that typically contains an online personal journal and that sometimes allows users to post their own opinions and commentary or other information.
[79] 509 U.S. 579 (1993).
[80] 522 U.S. 136 (1997).
[81] 526 U.S. 137 (1999).
[82] Pub. L. 93–595, §1, Jan. 2, 1975, 88 Stat. 1937; Apr. 17, 2000, eff. Dec. 1, 2000; Apr. 26, 2011, eff. Dec. 1, 2011.
[83] <http://www.law.cornell.edu/rules/fre/rule_702>.

According to Rule 702, *Testimony by Expert Witnesses,* a witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

a. The expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
b. The testimony is based on sufficient facts or data;
c. The testimony is the product of reliable principles and methods; and
d. The expert has reliably applied the principles and methods to the facts of the case.

In 2011, the National Academies published[84] the third edition of its *Reference Manual on Scientific Evidence,*[85] which was developed to guide judges as they encounter scientific evidence at trials. The cases are taken into consideration when government uses the "weight of evidence" to create public health policy and law.[86]

In a matter that is germane to the topic of this report, the Daubert case and the reference manual were both cited in a recent court decision in which the plaintiff claimed his exposure to low-level RF EMF emitted by electronics within his neighbor's house were triggering adverse health effects.[87] The court excluded the plaintiff's evidence because it was not scientifically reliable and consequently granted the defendant's motion for summary judgment for failing to demonstrate causation.[88]

Public Policy

The WHO published "Establishing a Dialogue on Risks from Electromagnetic Fields,"[89] a handbook intended as a guide for decision makers and those who craft policy to help reduce misunderstandings and improve trust through better dialogue when faced with a combination of public controversy, scientific uncertainty, and the need to operate or establish infrastructure facilities that emit EMF. The guide discusses risk assessment, risk perception by the public, and risk management. The document also calls out the need for involvement by individuals or organizations with the right set of competencies. It states that a combination of relevant scientific expertise, strong communication skills, and good judgment are required by those in the areas of management and regulation to properly respond to challenges presented by the topic. The handbook also provides references and suggested reading material for those who seek more information.

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[84] <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=13163>.
[85] <http://www.nap.edu/catalog.php?record_id=13163>.
[86] <http://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.2004.044727>.
[87] Firstenberg v. Monribot and Leith, No. D-101-CV-2010-00029, New Mexico 1st Dist, Santa Fe County, Sept 18, 2012.
[88] <http://www.casewatch.org/civil/firstenburg/dismissal_order.pdf>.
[89] <http://www.who.int/peh-emf/publications/EMF_Risk_ALL.pdf>.

Recent Studies and Expert Opinions

California Council on Science and Technology Report and Responses

In 2010, the CPUC initiated an investigation of smart meters. Several members of the California State Assembly asked the California Council on Science and Technology to provide assistance to the CPUC.

CCST is an independent, not-for-profit 501(c)(3) corporation established in 1988 by the California legislature. It is designed to offer expert advice to the state government and to recommend solutions to science- and technology-related policy issues. CCST's Board of Directors is composed of representatives from its sponsoring academic institutions, as well as the business and philanthropic communities.[90]

The Assembly's request to provide assistance was motivated by concerns expressed by the public about the possibility of health effects from exposure to RF EMF emitted by smart meters. In January 2011, CCST issued "Health Impacts of Radio Frequency from Smart Meters." The document was authored by a project team that consulted with over two dozen experts and sifted through more than one hundred articles and reports which CCST considered as providing a thorough, unbiased overview in a relatively rapid manner. The report identified four key findings: [91]

1. Wireless smart meters, when installed and properly maintained, result in much lower levels of RF exposure than many existing common household electronic devices, particularly cell phones and microwave ovens;
2. The current FCC standard[92,93,94] provides an adequate safety factor against known thermally induced health impacts of existing common household electronic devices and smart meters;
3. To date, scientific studies have not identified or confirmed negative health effects from potential non-thermal impacts of RF emissions such as those produced by existing common household electronic devices and smart meters; and
4. Not enough is currently known about potential non-thermal impacts of radio frequency emissions to identify or recommend additional standards for such impacts.

CCST did not undertake primary research of its own to address issues. Its response was limited to soliciting input from technical experts and to reviewing and evaluating available information from past and current research about health impacts of RF emitted by electric appliances in general, and more specifically by smart meters.

Response to CCST Report: County of Santa Cruz Health Services Agency

Following the release of the CCST report, Poki Stewart Namkung, Health Officer of the County of Santa Cruz Health Services Agency (Santa Cruz), issued a memorandum. The memo was published on January 13, 2012 and is entitled "Health Risks Associated with Smart Meters."[95] The document has gained notoriety for two reasons. The first reason is because it made assertions that were in direct opposition to the CCST report's key

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90 <http://www.ccst.us/about.php>.
91 <http://www.ccst.us/publications/2011/2011smart-final.pdf>.
92 <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65.pdf>.
93 <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf>.
94 <http://www.gpo.gov/fdsys/pkg/CFR-2011-title47-vol1/xml/CFR-2011-title47-vol1-sec1-1310.xml>.
95 <http://www.santacruzhealth.org/pdf/2012%20Report%20on%20SmartMeters.pdf>.

findings. The second reason is because the assertions made in the Santa Cruz memo have been used by some smart meter detractors to justify calls for a moratorium on installation of the devices.

The Santa Cruz memo stated that CCST's report did not account for the frequency of transmissions, any reflections of the emissions, banks of smart meters firing simultaneously, or distances closer than three feet. The memo also asserted that smart meters would emit RF EMF almost continuously and that it would not be possible to program them to not operate at 100% of a duty cycle (on continuously). It stated that because of these factors, one could not claim that Smart Meters do not exceed the time-averaged MPE limit adopted by the FCC.

The Santa Cruz memo also stated that RF EMF exposure is additive[96] and consumers may have already increased their exposures to RF EMF emissions in the home through the voluntary use of RF emitting devices.

Michigan Public Service Commission: SGTAP Assessment of Santa Cruz Memo

On March 20, 2012, the Michigan Public Service Commission (MPSC) asked the Smart Grid Technical Advisory Project (SGTAP) to review the Santa Cruz memorandum. SGTAP is located at the Lawrence Berkeley National Laboratory (LBNL) and provides technical assistance and training to state regulatory commissions on topics related to smart grid. Primary SGTAP contributors are Roger Levy, a Research Specialist and owner of Levy Associates, and Janie Page, a Science/Engineering Associate at LBNL and the former Managing Editor at Bioelectromagnetics Society. SGTAP's response provided an analysis[97] of the Santa Cruz memo and called its accuracy and substance into question.

SGTAP noted the following:

1. The Santa Cruz memo made statements that were technically and scientifically incorrect and not supported by any research;
2. The memo did not appear to provide a balanced representation of the research, the risks, or the mitigation options;
3. The memo was instead largely focused on scientifically unsupported claims related to EHS;
4. Only half of the memo's citations met the peer review criteria that Santa Cruz itself had identified as necessary to be considered as a valid source; and
5. Out of the remaining references, half came from a single issue of the journal Pathophysiology,[98] which would only provide a limited acknowledgement to other relevant health, scientific, or industry sources. By relying so much on the journal, Santa Cruz denied exposing itself to a diversity of sources.

Finally, SGTAP noted that science can work toward understanding the causes of any health effects if and when they are observed, but it has never been able to categorically declare *anything* as being completely safe.

SGTAP Comments on Hirsch Document

SGTAP pointed out that the Santa Cruz memo had referred to a five-page document authored by Daniel Hirsch, a lecturer on Nuclear Policy at the University of California, Santa Cruz. This is notable because Hirsch had critiqued the CCST report and opponents of smart meters have cited Hirsch's document as support for their argument.

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[96] Note that the letter stated *additive* not *cumulative*.

[97] <http://eetd.lbl.gov/ea/ems/reports/schsa-042012.pdf>.

[98] <http://www.sciencedirect.com/science/journal/09284680/16/2-3>.

SGTAP concluded that:

1. The Hirsch document was not a formal report. It was a private submittal to the CPUC that did not meet Santa Cruz's own standards for consideration;
2. The educational and professional credentials of neither Hirsch nor his assistants could be identified which may have qualified them to profess expertise on EMF radiation, health, or smart meter operations;
3. The Hirsch document was severely flawed in several respects:
   a. It made arbitrary assumptions;
   b. It changed results that had been independently measured for some RF EMF emitting devices to levels that are not physically possible; and
   c. It further inflated figures that already had been overstated in the CCST report.

EPRI also published a paper critical of the Santa Cruz memo. EPRI's comments will be discussed later in this report.

Michigan Public Service Commission: SGTAP Assessment of AAEM Submittal

On April 12, 2012, the American Academy of Environmental Medicine (AAEM)[99] submitted a letter[100] to the MPSC in opposition to the installation of smart meters in homes and schools. According to AAEM's website, it is an international association of physicians and other professionals interested in the clinical aspects of humans and their environment. AAEM states on its site that it is interested in expanding the knowledge of interactions between human individuals and their environment, as these may be demonstrated to be reflected in their total health.

The AAEM site states that it provides research and education in the recognition, treatment and prevention of illnesses induced by exposures to biological and chemical agents encountered in air, food, and water. The certifying board for AAEM is the American Board of Environmental Medicine (ABEM), founded in 1988.[101] It is worth noting that neither AAEM nor ABEM is recognized by the American Board of Medical Specialties (ABMS).[102,103] Furthermore, the certification criteria required by ABEM are relatively sparse compared to those of ABMS. ABEM requires that an applicant have three years' experience practicing environmental medicine, take the AAEM medical instructional courses, and pass a written and an oral exam.

In contrast, the ABMS certification process involves 3-7 years of residency in the specialty, testing in the specific area of practice, a fellowship program of 1-3 years' duration and an optional subspecialty certification. In order to maintain certification the doctor is subjected to an *ongoing* peer evaluation and improvement process designed and administered by specialists in the specific area of medicine.

As a result of AAEM's letter, MPSC asked SGTAP to review the submittal. SGTAP provided a report[104] on April 18, 2012, which focused on the logical foundation of the AAEM statements and the relevance of its citations to

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[99] <http://www.aaemonline.org/>.
[100] <http://efile.mpsc.state.mi.us/efile/docs/17000/0391.pdf>.
[101] <http://www.americanboardofenvironmentalmedicine.org>.
[102] <http://www.abms.org/Who_We_Help/Physicians/specialties.aspx>.
[103] The ABMS was established in 1933, and is composed of approved medical boards which represent 24 broad areas of specialty medicine. ABMS is the largest physician-led specialty certification organization in the U.S. The American Medical Association's Council on Medical Education plays a significant role in ABMS.
[104] <http://eetd.lbl.gov/ea/emp/reports/aaem-042012.pdf>.

the smart meter issues. SGTAP did not comment on the technical merits of the individual research citations in the AAEM letter.

The SGTAP assessment found the following four aspects of the AAEM submittal to be problematic:

1. AAEM's assertion that research established causality of non-thermal effects;
2. The AAEM research citations and references were unrelated to smart meters;
3. AAEM's claims of electromagnetic hypersensitivity; and
4. AAEM's statements about the RF environment.

The following items provide detail on SGTAP's findings.

Aspect 1: SGTAP's Findings on AAEM's Assertion of Non-thermal Effects Causality

When considering the purported causality of non-thermal effects, recall that RF represents an extremely wide range of radio waves from 3 kHz to 300 GHz that spans eight orders of magnitude.[105] SGTAP stated that the RF EMF range cannot be generalized down to a single signal and that RF EMF is distinguished by a variety of independent characteristics, including frequency and intensity.

SGTAP pointed out that existing research has emphasized the unique characteristics and potential differences in effects from various RF EMF signals and sources. Thus, SGTAP concluded, an RF EMF effect reported at one frequency from one source cannot be presumed to imply an effect at another frequency from a completely different source.

The thermal effects observed as a result of exposure to RF EMF emissions at lower intensities are due to known mechanisms and could imply larger effects at a higher intensity.

Non-thermal effects are different because they appear to be related to distinct characteristics of the biological system being exposed and that symptoms or effects appear at specific frequencies or at distinct combinations of fields but not at others. Because there are no identified clear mechanisms for non-thermal RF EMF effects, there is no basis for someone to extrapolate observed non-thermal effects from one RF EMF source to another.

The AAEM submittal referred to the nine "Hill Criteria"[106] and the results of research studies which AAEM had extended to smart meters. Note that the criteria are most often used for assessing evidence of causation in epidemiological studies to test whether a particular agent is the cause of a selected effect. The criteria are typically employed when it is difficult to establish controls for all experimental variables. Using the criteria in research requires one to infer the causative agents from observational data.

SGTAP pointed out that inference is not proof and stated that the criteria cannot be applied when there are no research-related observational results. SGTAP concluded that it is not appropriate to presume an effect when the RF EMF sources differed in frequency, intensity, and proximity to critical biological tissues. Table 1 was included in the SGTAP report and addresses each criterion in relation to cell phones and smart meters. Reviewing the assessment of these criteria, it appears that the criteria have not been satisfied for cell phones, but it is quite obvious that the Hill criteria have not been satisfied for smart meters. No matter how well the criteria may or may not have been satisfied for cell phones, the significant differences between the two

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[105] An order of magnitude is a Power of Ten, so eight orders of magnitude would be 10^8, or a 1 followed by eight zeroes (100,000,000).
[106] <http://www.edwardtufte.com/tufte/hill>.

technologies and the absence of research that specifically addresses smart meter operating characteristics make any attempt to assess smart meters using Hill's criteria moot.

Table 1: SGTAP Assessment Using Hill Criteria

Hill Criteria	Cell phones	Smart Meters
Strength: How large is the effect?	No widespread disease has yet been reported.	No published, peer-reviewed, scientific research at this time.
Consistency: Has the same association been observed by others, in different populations, using a different method?	Limited evidence from INTERPHONE study,[107] interpreted differently by different researchers. Opponents of smart meters focus strictly on Hardell's positive results without acknowledging the other results in the INTERPHONE study.	No published, peer-reviewed, scientific research at this time.[108]
Specificity: Does altering only the cause alter the effect?	A variety of studies has looked at changes in experimental setup to alter the source or size of the exposure with compelling results, most of which are related to distinct endpoints (e.g. oxidative stress markers and pathological changes in brain tissue in AAEM citation 16)	No published, peer-reviewed, scientific research at this time.
Temporality: Does the cause precede the effect?	Hard to discern in some epidemiology studies because hard to know state of individuals prior to study. Generally well controlled in lab studies.	No published, peer-reviewed, scientific research at this time, although some people claim a particular set of symptoms arise shortly after meters are installed.
Biological gradient: Is there a dose response?	Intensity of fields is often assumed as dose in a thermal model. For non-thermal effects, these criteria may not apply until we have a better understanding of dose.	No published, peer-reviewed, scientific research at this time.
Plausibility: Does it make sense? (Hill noted that knowledge of the mechanism is limited by current knowledge).	Mechanisms have not been well developed other than heating processes, where it is assumed that energy accumulates until dissipated.	No published, peer-reviewed, scientific research at this time.

107 <http://ije.oxfordjournals.org/content/39/3/675.full.pdf>.

108 For the purposes of the Hill criteria, reported symptoms need to be derived from well-structured research, not self-reported anecdotal reports (e.g. Internet blogs, newspaper articles, complaints/statements to regulatory commissions, etc.).

Coherence: Does the evidence fit with what is known regarding the natural history and biology of the outcome?	Limited coherence – many of the reported effects have unknown etiologies.	No published, peer-reviewed, scientific research at this time.
Experiment: Are there any clinical studies supporting the association?	There are some studies suggesting effects under certain circumstances.	No published, peer-reviewed, scientific research at this time.
Analogy: Is the observed association supported by similar associations?	Presumed to be supported by earlier (generally higher power) microwave studies.	Presumed to be supported by cell phone studies.

Aspect 2: SGTAP's Findings on AAEM's Research Citations and References

SGTAP stated that the citations and references in AAEM's letter were unrelated to smart meters. Smart meters operate in the frequency range of 902 - 928 MHz, and at an intensity of less than 1 watt, but the AAEM submittal cited references in which the frequencies and exposures measured appear to be substantively different from the fields that have been measured from smart meters.

In the one study cited by AAEM that did use a frequency in proximity of the range used by smart meters, the reported Specific Absorption Rate was at much greater field strength than that of a smart meter. Also, the test subject animals' proximity to the RF EMF source most likely would have been impossible to duplicate with a normal wall-mounted smart meter.

Aspect 3: SGTAP's Findings on AAEM's Claims of Electromagnetic Hypersensitivity

SGTAP found two problems with AAEM's claim that EHS had been documented in controlled and double-blind[109] placebo controlled conditions and in which 100% of subjects showed reproducible reactions to a frequency to which they were supposedly most sensitive. SGTAP pointed out that disagreements to the purported reproducibility of these reactions have been documented.

SGTAP also stated that the researcher AAEM had cited claimed that the frequencies involved in living systems are so precise that even the *phase* of a frequency was significant in research results. SGTAP concluded that while AAEM may have considered its cited researcher as credible, that finding would be in direct opposition to AAEM's attempt to extrapolate results from studies that used another frequency.

SGTAP also performed a detailed meta-analysis[110] of available literature and found that there was no evidence that study participants previously described as being "hypersensitive" had an improved ability to detect RF EMF. This was further reinforced by the conclusions drawn by the World Health Organization's (WHO) examination of EHS. The organization found that well-controlled double-blind studies showed no correlation between symptoms and RF EMF exposure.

[109] In a double-blind experiment, neither the test subjects nor the researchers know who belongs to the control group and who belongs to the experimental group. This is done to lessen the influence of any prejudices and unintentional physical cues on the results.

[110] A meta-analysis is a "study of studies," i.e. a systematic method of evaluating statistical data based on results of several independent studies of the same problem.

SGTAP made special note of the fact that the references cited by AAEM to describe claimed sensitivities among self-identified EHS individuals were at very specific frequencies, none of which were associated with the operation of smart meters.

Aspect 4: SGTAP's Findings on AAEM's Statements about the RF Environment

SGTAP stated that recent measurements revealed that smart meters contribute only a small fraction of the total RF EMF emissions in a typical environment to which the general population is routinely exposed. SGTAP concluded that only a negligible reduction in total existing RF EMF exposures would result if smart meters were eliminated entirely.

Electric Power Research Institute

EPRI[111] is an independent, nonprofit organization that conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. EPRI provides technology, policy, and economic analyses to promote long-range research and development planning and supports research in emerging technologies. Scientists and engineers from EPRI, along with experts from academia and industry, address the challenges of electricity including reliability, efficiency, health, safety, and the environment.

For more than 30 years, EPRI has taken an active role in characterizing electromagnetic environments associated with power frequency transmission and distribution systems. More recently, the organization has done the same with RF EMF from smart meters. In February 2010, EPRI released a brief overview on RF EMF exposure associated with smart meters entitled "A Perspective on Radio-Frequency Exposure Associated with Residential Automatic Meter Reading Technology."[112] Since that time, EPRI has performed multiple investigations on RF EMF, and the results have been shared with regulators and industry as well as with the general public in an effort to foster a common understanding of RF EMF environments.

EPRI Technical Report on RF Emissions from Two Models of Smart Meters

EPRI has published several documents related to the RF EMF emitted by smart meters. In a December 2011 document[113], EPRI presented the results of a study by Richard Tell Associates[114] which EPRI had sponsored. Richard Tell Associates is a scientific consulting business focused on electromagnetic field exposure assessment, compliance with applicable standards and regulations on RF and power frequency fields and training related to the measurement, analysis and interpretation of electromagnetic fields.

The EPRI study was performed over a period of approximately six months during 2011 and analyzed two different wireless smart meters, a General Electric-I210 and a Landis+Gyr Focus AXR-SD, that Pacific Gas & Electric (PG&E) was in the process of deploying in its service territory. The meters contained two low power transmitters. One transmitter was 1W, to be used for communication in a mesh network, while the other was 0.1W, intended for a potential future Home Area Network (HAN). Each meter was also equipped with one of two different wireless communication packages developed by Silver Spring Networks.

The study found that the RF EMF field levels from the smart meters were below the exposure limits specified by the FCC. Furthermore, calculations determined that as the system was operating, nearly 99.9% of the

[111] <http://www.epri.com/>.
[112] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001020798>.
[113] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001021829>.
[114] <http://www.radhaz.com/>.

meters transmitted 1% or less of the time, and 99% of the meters transmitted less than 0.4% of the time. FCC exposure limits for the general public take these duty cycles[115] into account when estimating potential exposures and are based on a 30-minute average of power density across the body.

Preliminary measurements on the meters were conducted to:

- Determine the magnitude of the RF fields generated by the 1W mesh transmitter;
- Examine the meter's directional characteristics;
- Observe any unusual low frequency emissions in the 5 Hz to 100 kHz band that might be produced by the electronic circuits within the meters; and
- Measure the attenuation by a simulated stucco wall, common in many California homes.

In the next phase of the study, on-site measurements at six residential locations were conducted. This was done to determine typical indoor values of the RF EMF produced by the smart meter installed on a home. In addition, measurements were taken of the composite RF EMF environment where collections of smart meters were aggregated in a small space. This procedure was performed at three different apartment complexes, including one where 112 smart meters were collocated. Short-term duty cycles for several smart meters were also measured. Finally, the investigators took field measurements at a single data collector which gathers meter data from potentially thousands of residences.

Calculating Smart Meter RF EMF Emission Duty Cycles

The study collected and analyzed data transmissions from 88,296 smart meters through the utility's data management system. This large sample revealed the statistical distribution of meter duty cycles and enabled the calculation of the value for time-averaged potential exposure.

The EPRI report stated that the analysis identified one meter in 88,296 that exhibited a maximum duty cycle of 13.9%. It also found that half of the meters exhibited duty cycles not exceeding 0.0465%, 99% of meters had duty cycles not exceeding 0.355%, 99.9% had duty cycles at or below 1.12%, and 99.99% of meters had maximum duty cycles of 4.53% or less. The data confirmed that smart meters, while transmitting intermittently throughout the day, create RF fields for only very small fractions of the day. For example, half of all meters would be expected to actually transmit no more than 40 seconds per 24 hour day.

Considering the Directionality of RF EMF

The study also investigated the directional emission patterns of the meters. It found that the forward direction was strongest; rearward-directed fields were reduced by a factor of ten, and in some cases reductions of a factor of 100 were measured.[116]

Considering Groups of Meters

EPRI's report demonstrated that groups of smart meters mounted on apartment buildings at three different locations did not result in greater peak values of RF EMF fields than those produced by an individual meter. The study did find that average field magnitudes were higher due to the operation of multiple meter

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[115] Duty cycle is the time that the radio module in a smart meter is emitting as a fraction of the total time period being considered.

[116] To be more precise, the reductions were 10 and 20 decibels respectively.

transmitters but that higher average composite duty cycles did not change the conclusion that such exposures are compliant with the established FCC limits.

Considering the HAN Transmitter

The HAN radio inside a smart meter is not currently implemented in PG&E's deployment, but the study found that when it was activated, the resulting EMF RF fields were substantially weaker due to their lower effective isotropic[117] radiated power (EIRP).[118] These radios also complied with the FCC exposure limits.

Report Conclusions on RF EMF Exposure

The EPRI report concluded that individuals in smart meter-equipped homes are commonly exposed to RF EMF emissions that are orders of magnitude less than what would occur for an individual standing immediately adjacent to and in front of the meter. It stated that the measurements performed in the six subject California residences found that 99% of the measured peak values were less than 0.8% of the MPE for the general public tier, and 90% of the measured values were less than 0.1% of the MPE.

The report stated that RF EMF emissions from smart meters that transmit data wirelessly are constrained by the low power of the transmitter's power and by the antenna's gain. Estimating smart meter fields is a straightforward calculation based on the EIRP of the meter. Locations where the greatest exposure can occur warrant no special consideration of reflections.

In summary, the EPRI report stated that the smart meter emissions are minute compared to the applicable FCC exposure limits. It also concluded that the smart meters comply with the FCC MPEs whether:

- The peak measured fields are corrected for meter duty cycles;
- Spatial averaging or any other factor that reduces RF fields, such as the construction materials of homes is considered;
- The meters exist in a large group or individually; or
- Individuals are outside near the smart meter or inside their residence.

As expected, the EPRI study found that the strongest fields occurred at the closest distance that measurements were performed (one foot). Typical peak fields at this distance were found to be about 10-15% of the MPE. The study also found that time-averaged and spatially-averaged values, at this point of maximum peak field, were estimated to be at most 0.14% of the FCC MPE, depending on the activity of the meter.

EPRI Comments on the Santa Cruz and AAEM Memoranda

EPRI also provided commentary[119] on the documents that the County of Santa Cruz Health Services Agency and AAEM had issued in response to the report from the CCST. EPRI stated that neither the Santa Cruz memo nor the AAEM document accounted for the large body of research on RF EMF that has been conducted over the past 50 years or the "weight-of-evidence" approach utilized by a large number of expert groups and panels that have convened over the years to assess the literature on RF health science.

[117] Isotropic means "uniform in all orientations."

[118] EIRP is the amount of power that a theoretical antenna that evenly distributes power in all directions would emit to produce the peak power density observed in the direction of maximum antenna gain.

[119] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001024952>.

EPRI concluded:

> "The transmittal from the Santa Cruz County health officer reflected a misunderstanding of several terms and concepts, including some of the basic principles of how smart meters work."

FCC RF EMF Exposure Guidelines

The 1997 FCC rule on RF EMF exposure was crafted from two earlier guidelines. The first guideline was published by the NCRP in 1986.[120] The second guideline was issued by the IEEE in 1991 and revised in 2005.[121] Before the FCC published its rule, it received endorsements from the U.S. Environmental Protection Agency (EPA), the FDA, and the U.S. Occupational Safety and Health Administration (OSHA). The EPA reaffirmed its opinion in 1999 and 2002.

Both sets of guidelines originated from an extensive review of the literature published in the fields of biology and health, regardless of whether the research had been conducted at non-thermal levels of exposure. NCRP and IEEE both concluded that the only established health effects of RF EMF were associated with tissue heating and that there were no confirmed adverse effects from RF exposure levels below an exposure threshold associated with an elevation in body temperature of about 1.8° F (1° C).

EPRI stated that since the FCC rulemaking, experts have revisited the expanding body of scientific evidence concerning potential health effects from RF EMF exposure. The conclusions were consistent with the position taken by the FCC in 1997.

Furthermore, following a comprehensive review of the scientific literature, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published exposure limits in 1998 and reaffirmed them in 2009, while the IEEE issued its exposure limits in 2005. EPRI stated that both organizations' numbers were very similar to those of the FCC.

EPRI Addresses the WHO Classification of EMF as a 2B Carcinogen

In the spring of 2011, concerns about RF EMF exposures received significant visibility when the International Agency for Research on Cancer (IARC), a division of the WHO, published the results of its evaluation of potential cancer risks from RF exposures. The "IARC Monographs" identify environmental factors which can increase the risk of cancer in humans. These factors include chemicals, complex mixtures, occupational exposures, physical agents, biological agents, and lifestyle factors. National health agencies can use this information as scientific support for their actions to prevent exposure to potential carcinogens.[122]
According to EPRI, based on what can be considered as limited epidemiologic evidence in studies of cell phones and also limited evidence from a small fraction of all reported animal experiments, IARC classified radiofrequency electromagnetic fields as a "possible" or a Group 2B carcinogen.

To help put things into perspective, one must first understand the hierarchy of IARC categories. The categories, also known as Monograph Groups, consist of the following:

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[120] "NCRP Report No. 86 - Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields".
[121] <http://standards.ieee.org/findstds/standard/C95.1-2005.html>.
[122] <http://monographs.iarc.fr/>.

- Group 1: Carcinogenic to Humans (i.e., sufficient evidence);
- Group 2A: Probably Carcinogenic (less than sufficient evidence);
- Group 2B: Possibly Carcinogenic (limited evidence, less supportive evidence than 2A);
- Group 3: Not Classifiable (inadequate and/or insufficient evidence for classification).[123]

With reference to Monograph Groups 2A and 2B, IARC stated:

> "The terms probably carcinogenic and possibly carcinogenic have no quantitative significance and are used simply as descriptors of different levels of evidence of human carcinogenicity, with probably carcinogenic signifying a higher level of evidence than possibly carcinogenic."[124]

EPRI stated that the IARC 2B classification of RF EMF provides for a range of qualitative interpretations concerning its potential carcinogenicity. This IARC 2B classification indicates that more research information would be required for a more definitive statement in either direction.

EPRI continued, saying that the weight of current evidence still does not provide a basis to conclude that RF EMF can be considered as being "probably" carcinogenic. EPRI also indicated that IARC has near-term plans to evaluate the potential effects of RF EMF on all health outcomes, including cancer.

PUCT Staff's Observations on IARC 2B Carcinogens

There are over 200 substances in the IARC's 2B category, many of which have lengthy chemical names. Casual observers of such a list may become alarmed when they recognize a familiar item on it.[125]

Opponents of smart meters have noted the pending inclusion of RF EMF into the IARC 2B classification, and typically mention the pesticide DDT (dichlorodiphenyltrichloroethane) and elemental lead as also having been placed into the same classification (DDT was added in 1991, lead was added in 1987).

All this must be examined objectively and in the proper context.

Decades ago, DDT was found to have a demonstrable negative environmental impact widely viewed as outweighing its perceived benefits and found to accumulate in living tissue, leading to obvious health issues. For those reasons, it was removed from the market. Note that the potential for cancer is not why the substance was withdrawn.

Lead is also a bioaccumulative substance and has known toxic effects, such as interfering with a variety of body processes including those of the nervous system. As a result, its use has been continually reduced over the past few decades. Again, the potential for lead to cause cancer is generally not why the use of the substance has fallen out of favor.

To date, there is insufficient evidence to declare with confidence that either one of these substances is cancer-causing. Otherwise by now, one or both substances most likely would have been placed under a different IARC classification, namely one that required a higher level of evidence.

[123] <http://monographs.iarc.fr/ENG/Preamble/CurrentPreamble.pdf>.
[124] <http://monographs.iarc.fr/ENG/Preamble/currentb6evalrationale0706.php>.
[125] See the References and Resources page for the entry under "Way, Tom."

In exploring comments made by some smart meter opponents filed with the Commission or found while researching the issue on the Internet, elemental lead and DDT have been mentioned in conjunction with RF EMF, but there has been no mention of the following well-known, common substances that are also included in the 2B Classification by the IARC:

- Coffee (added 1991);
- Pickled vegetables (added 1993); and
- Talc body powder (added 2010).

Lead and DDT are two substances that are widely known to cause health effects other than cancer and therefore carry with them a stigma. To mention them while excluding other substances which are both commonly used and generally considered benign, such as the ones listed above, and without the proper context, imparts a negative bias. This negative bias may prejudice the observer and alarm and confuse those who may have valid concerns about health and are attempting to understand rather complex concepts.

EPRI Workshops on RF Emissions and Health

In 2011, EPRI hosted two workshops to discuss the IARC classification. A report on the proceedings is available to the public in a document entitled "Program on Technology Innovation: Environmental and Health Issues Related to Radiofrequency Emissions from Smart Grid Technologies - Summary of Two Workshops."[126]

The purpose of the first workshop was to more specifically identify emerging technologies within the electric utility industry whose operation would result in EMF emissions. Such emissions may be produced for purposeful reasons, namely for communications, or might be a byproduct of a technology, such as emissions from appliances powered with variable speed drives.

The second workshop was a gathering of international scientists who shared their expertise to review the most important health issues associated with RF exposure and to identify priorities for further research. This workshop covered all aspects of RF science including exposure assessment, epidemiology, laboratory studies on both animals and humans, and biophysical mechanisms.

As a result of the workshops, EPRI issued a report that functions as a backdrop for potential future research to address environmental and health issues regarding smart grid technologies. It concluded:

- Current research regarding the health implications associated with RF emissions of new technologies has focused primarily on the nearly universal use of cell phones;
- Little information concerning characterization of exposure from projected smart grid and associated technologies is currently available;
- Though no adverse effects of "non-thermal" exposures have been identified, various unresolved questions remain, including a consistent observation of slightly altered brain wave activity in human subjects exposed to radio-frequency fields under laboratory conditions; and
- That the organization was well positioned to inform and educate all stakeholders about environmental risks and risk management options associated with technology deployment and operation.

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[126] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001024737>.

EPRI Investigations of RF EMF from Smart Meter Technology and Smart Grid Components

In 2010, EPRI published a 222-page technical report on its investigation of a particular smart meter entitled "An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter."[127] The results indicated that RF EMF from the smart meter was well below the MPE established by the FCC.

For instance, at a distance of one foot, the RF EMF from a meter was not expected to exceed 0.8% of the MPE established by the FCC. For the cell relay, the study found that the RF field would not exceed 0.2% of the MPE. Even at very close distances, such as one foot directly in front of the meter and making the highly unrealistic assumption that the transmitters operate at 100% duty cycle, the resulting exposure was still found to be less than the FCC MPE.

When viewed in the context of a realistic and typical exposure distance of ten feet, the RF fields were much smaller: about 0.008% for the meter and about 0.002% of MPE for the cell relay.

EPRI's study stated that for occupants of a home equipped with a smart meter, interior RF fields were expected to be less than one-tenth as intense simply due to the directional properties of the meter. The investigation found that when a stucco[128] home's construction was included, the realistic value of the interior RF field would be attenuated to about 0.023% of the MPE for a meter and about 0.065% for a cell relay.

The investigators stated that regardless of duty cycle values for meter and cell relay meters, typical exposures that resulted from the operation of smart meters were very low and complied with scientifically-based human exposure limits by a wide margin.

EPRI also produced a brief case study in February 2011 on another smart meter with similar results under the title "Radio-Frequency Exposure Levels from Smart Meters: A Case Study of One Model."[129] In the interest of brevity and to avoid repetition, the findings of that EPRI publication are summarized in Table 2 below. The entire referenced document is publicly available from EPRI.

[127] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001021126>.
[128] Stucco is a common home construction material in California, where this analysis was performed.
[129] <http://my.epri.com/portal/server.pt?Abstract_id=000000000001022270>.

Table 2: EPRI Findings – Radio Frequency Levels from Various Sources[130]

Source	Frequency	Exposure Level (mW/cm^2)	Distance	Time	Spatial Characteristic
Cell phone[(131)]	900 MHz and 1800 MHz	1-5	At ear	During call	Highly localized
Cell phone base station	900 MHz and 1800 MHz	0.000005-0.002	Tens to a few thousand feet	Constant	Relatively uniform
Microwave oven	2450 MHz	~5 0.05-0.2	2 inches 2 feet	During use	Localized, non-uniform
Local area networks[(132)]	2400 MHz or 5000 MHz	0.0002-0.001 (wireless router) 0.000005-0.0002 (client card)	3 feet	Constant when nearby	Localized, non-uniform
Radio/TV broadcast	Wide spectrum	0.001 (highest 1% of population) 0.000005 (50% of population)	Far from source (in most cases)	Constant	Relatively uniform
Smart meter[(133)]	900MHz and 2400 MHz	0.0001 (250mW, 1% duty cycle) 0.002 (1 W, 5% duty cycle) 0.000009 (250 mW, 1% duty cycle) 0.0002 (1 W, 5% duty cycle)	3 feet 10 feet	When in proximity during transmission	Localized, non-uniform

EPRI has also published a document that outlines eight projects involving the study of EMF and RF health and safety which the organization plans to perform in 2013. Most of these projects have multiple parts, several of which are expected to continue into subsequent years. The organization refers to this series of investigations and their resulting products as Program 60.[134] Its estimated funding for the program in 2013 is $5 million. Among the products to be completed in 2013 are:

- A peer review of literature regarding investigations of potential EMF/RF interference with implanted medical devices (e.g. pacemakers);
- A technical report to address emerging concerns about potential EMF effects on behavior and health of honeybees and cattle; and
- A technical update on RF exposure from wireless sources.

[130] FCC rule: From 300 MHz to 1500 MHz, MPE = 0.2 x f/300 mW/cm^2 (f is frequency in MHz); for 1500 MHz and greater, MPE = 1 mW/cm^2. For example, at 900 MHz MPE = 0.2 x (900/300) mW/cm^2 = 0.6 mW/cm^2. Note: Compliance for cell phones is provided by manufacturers, and expressed in terms of SAR, which cannot exceed 1.6 W/kg for any single gram of tissue.

[131] Based on a 3-inch, 250 mW antenna emitting in a cylindrical wave front.

[132] Wireless router based on a 30-100 mW isotropic emitter. Client card based on: Foster KR. 2007.

[133] Based on spatial peak power density with 6 dB (x4) antenna gain. For instantaneous power density during transmission, multiply the value for 1% duty cycle by 100, and the value for 5% duty cycle by 20.

[134] <http://mydocs.epri.com/docs/Portfolio/PDF/2013_P060.pdf>.

EPRI Comments on Sage Report

In January 2010, Sage Associates,[135] an environmental consulting firm whose principal is Cindy Sage,[136] issued a report entitled "Assessment of Radiofrequency Microwave Radiation Emissions from Smart Meters."[137] The report compared RF field levels of smart meters to the FCC's exposure limits and concluded that smart meters and collector meters installed in California were likely to violate the FCC limits, even under normal conditions of installation and operation. The report also compared field levels from smart meters to those from studies that reported biological and health effects.

In February 2010, EPRI addressed the research findings cited in the Sage report in a document titled "EPRI Comment: Sage Report on Radio-Frequency (RF) Exposures from Smart Meters."[138] EPRI found that:

- The Sage report misapplied the specifications in the FCC rule;
- The report findings had not been replicated or were inconsistent with the results of other studies; and
- Virtually every recent mainstream expert scientific review of the RF health literature conducted in North America and Europe either had not confirmed the effects cited in the report or found them indefinite.

Joint White Paper of EEI, UTC, and AEIC

In March 2011, Edison Electric Institute (EEI), Utilities Telecom Council (UTC), and Association of Edison Illuminating Companies (AEIC) jointly issued a white paper[139] entitled "A Discussion of Smart Meters and RF Exposure Issues."

The paper discusses how the location, distance from the transmitter, shielding by meter enclosures, attenuation of building materials, direction of RF emissions, and transmit duty cycle have a significant effect on RF EMF exposure levels. It also reviews the conclusions of several Smart Meter RF studies and actual measurements of Smart Meter RF emissions. Other observations made in the paper include:

- All smart meter radio devices must be certified to the FCC's rules;
- Tests simulating multi-family metering locations containing several meters in close proximity have shown RF exposure levels dramatically less than the FCC limits;
- The FCC limits on MPE for application to the general public were set using safety factors one-fiftieth (1/50th) of the levels of known effects;
- Exposure levels drop significantly:
    - with the distance from the transmitter;
    - with spatial averaging; and
    - in living spaces due to the attenuation effects of building materials.
- Due to shielding of the meter enclosure and signal patterns, RF exposure from the rear of a metering location is nominally one-tenth of that in front of the meter and dramatically below FCC limits, not including the spatial averaging and building material attenuation reductions;

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135 <http://www.silcom.com/~sage/emf/index.html>.

136 The Sage website states that Mrs. Sage has been involved in EMF issues as an environmental consultant and public policy researcher since 1982. She holds an M.A. degree in Geology and a B.A. in Biology.

137 <http://sagereports.com/smart-meter-rf/>.

138 <http://my.epri.com/portal/server.pt?Abstract_id=000000000001022639>.

139 <http://www.aeic.org/meter_service/smartmetersandrf031511.pdf>.

- For measurement and calculation purposes, some studies use a 100% duty cycle. However, the maximum operational duty cycle for smart meter systems is less than 50% to prevent message traffic congestion and data packet collisions. The typical duty cycle for smart meter systems is between 1% and 5%;
- An RF exposure comparison of a person talking on a cell phone and a person three and ten feet from a continuously operating smart meter would result in smart meter RF exposure that is 0.08% - 0.8% of a cell phone; and
- In test environments simulating operational conditions, for power (0.250 - 2 watts), duty cycle (2% – 5%) at close distance (one foot) from in front of the transmitter, smart meters produce very low RF exposure to the consumer. They are typically well under 10% of the FCC exposure regulations.

The paper stated that before utilities accept and deploy smart meters, the devices must meet a number of national standards and comply with state and local codes designed to ensure proper operation, functionality, and safety. Specifically, smart meters and smart meter installations are typically designed to conform with and certified to comply with:

- ANSI C12.1, 12.10, and 12.20 standards for accuracy and performance;
- National Electrical Manufacturers Association (NEMA) SG-AMI 1-2009 "Requirements for Smart Meter Upgradeability";
- FCC standards for intentional and unintentional radio emissions and safety related to RF exposure, Parts 1 and 2 of the FCC's Rules and Regulations [47 C.F.R. 1.1307(b), 1.1310, 2.1091, 2.1093];
- Local technical codes and requirements; and
- Utility-specific and customer beneficial business and technical requirements.

The paper also discusses how manufacturers conduct performance and life cycle testing for meters and for major design changes to existing meters, including hardware and firmware. Once the testing is successfully completed, components of the smart meter system are certified by a utility or a third party for production and purchase. Finally, the paper outlines the process utilities use to accept materials and to evaluate each shipment of equipment for quality and compliance to specification after certification and purchasing.

Government and Academia

National Cancer Institute at the National Institutes of Health

The National Cancer Institute (NCI)[140] was established by Congress in 1937 and is one of 27 Institutes and Centers that form the National Institutes of Health (NIH). The NIH is one of the world's foremost medical research centers and is a part of HHS. NIH officials reported that the agency has provided about $35 million for research on health effects of RF energy from mobile phone use from 2001 to 2011.[141]

NCI's main responsibilities include coordinating the National Cancer Program, conducting and supporting cancer research, training physicians and scientists, and disseminating information about cancer detection, diagnosis, treatment, prevention, control, palliative care, and survivorship. Most of NCI's budget is used to fund grants and contracts to universities, medical schools, cancer centers, research laboratories, and private firms in the U.S. and about 60 other countries around the world.

One result of NCI's responsibilities to collect, analyze, and disseminate the results of cancer research conducted in the U.S. and in other countries is its webpage "Cell Phones and Cancer Risk,"[142] that concisely provides information in a Question and Answer format. While the webpage does not explicitly address the wireless communications technologies used by smart meters, if one accepts the notion that these technologies are similar to cell phones, the page offers useful information.

Key points made by NCI:

- Cell phones emit RF energy, a form of non-ionizing EM radiation which can be absorbed by tissues closest to where the phone is held;
- The amount of RF energy to which a cell phone user is exposed depends on the technology of the phone, the distance between the phone's antenna and the user, the extent and type of use, and the user's distance from cell phone towers; and
- Studies thus far have not shown a consistent link between cell phone use and cancers of the brain, nerves, or other tissues of the head or neck. More research is needed because cell phone technology and how people use cell phones have been changing rapidly.

These conclusions were mainly based on the results of some recently published studies including one from early 2012. NCI had reported on the results[143] indicating that while cell phone use in the U.S. had increased substantially over the period from 1992 to 2008 (from nearly zero to almost 100 percent of the population), the country's trends in glioma, the main type of brain cancer hypothesized to be related to cell phone use, did not mirror that increase. Results of this study were published online March 8, 2012 in the British Medical Journal.[144]

The NCI statement generally agreed with its comments[145] regarding the Interphone study[146] released nearly two years prior. The study was an international collaboration and the largest of its kind at the time which had

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[140] <http://www.cancer.gov/cancertopics/factsheet/NCI/NCI>.
[141] <http://www.gao.gov/assets/600/592901.pdf>.
[142] <http://www.cancer.gov/cancertopics/factsheet/Risk/cellphones>.
[143] <http://www.cancer.gov/newscenter/pressreleases/2012/GliomaCellPhoneUse>.
[144] <http://www.bmj.com/content/344/bmj.e1147>.
[145] <http://www.cancer.gov/newscenter/pressreleases/2010/Interphone2010Results>.
[146] <http://ije.oxfordjournals.org/content/39/3/675.full.pdf>.

looked at both glioma and meningioma, another form of brain cancer. It was published online in the International Journal of Epidemiology on May 17, 2010.

FCC Letter: Equipment Authorization, Exposure Limits, and Interference

The FCC is an independent U.S. government agency.[147] The agency was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. Only three commissioners may be members of the same political party. None of them can have a financial interest in any Commission-related business. The commissioners supervise all FCC activities, delegating responsibilities to staff units and Bureaus.

The FCC's OET laboratory oversees the Equipment Authorization program. This program provides guidelines for the sale and use of equipment using the radio frequency spectrum. The devices subject to these rules must comply with the regulations in order to be considered as operating properly and to not create harmful interference. Subject RF devices may not be imported and/or marketed until they have demonstrated compliance with the technical standards specified by the FCC. These standards may be found in the rule section that governs the service wherein the equipment is to be operated. Financial penalties can be assessed if one does not comply with the appropriate FCC equipment authorization procedure. The Equipment Authorization procedures are publicly available for review.[148]

In March 2010, Cindy Sage sent a letter to the FCC with questions on several topics such as the agency's RF exposure limits, adjacent smart meter installations, and the potential for interference with other devices, especially medical devices. In August 2010, Julius Knapp, Chief of the FCC's Office of Engineering and Technology, responded.[149] The FCC letter explained that SAR evaluations were unnecessary with devices not held against the body and that power density (field strength) measurements were a sufficient and appropriate measure of exposure. The letter explained that FCC field strength limits and SAR limits are both time-averaged figures.

The FCC response pointed out that when the agency grants equipment authorizations (EA), it takes into account the peak power of the device because it is relevant to interference concerns. In contrast, exposure evaluations utilize maximum time-averaged power because that measurement takes into account how often a device will transmit. The purpose of a smart meter is to provide very infrequent information, so it transmits only in occasional bursts.

The FCC letter also addressed multiple adjacent smart meter installations. Since each smart meter has its own antenna, the separation distance of a person from most of the antennas is relatively large so that the potential exposure is quite small. Only one transmitter at a time can communicate with the collector to avoid the packets of data colliding with one another. Therefore, exposure from multiple signals at once does not occur. Signal strength decreases exponentially with distance, and there are additional losses of signal due to not being in the line of sight. In order for a device to be granted an EA, even banks of collocated meters must be compliant to the FCC's public exposure limits. Finally, the letter explained that auditing and review of EA grants is a routine function of the OET laboratory.

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[147] <http://transition.fcc.gov/aboutus.html>.
[148] <http://transition.fcc.gov/oet/ea/procedures.html>.
[149] <http://www.ccst.us/projects/smart/documents/Sage_Letter_from_%20Knapp_FCC.pdf>.

The FCC letter also addressed interference with medical devices, explaining that smart meters operate under Part 15 of the FCC Rules,[150] which specify power limitations to avoid interference. It stated that certain medical devices may need special precautions in many other environments, and that these are generally considered during FDA approval of the individual medical device.

GAO Report: Exposure and Testing Requirements for Mobile Phones Should Be Reassessed

In July 2012, the U.S. Government Accountability Office (GAO) issued a report[151] that recommended the FCC formally reassess and, if appropriate, change its current RF energy exposure limit and mobile phone testing requirements. It suggested that consideration be given to likely usage configurations, particularly when phones are held against the body. The FCC noted that it is currently considering a draft document which has the potential to address the GAO's recommendations.

The GAO also noted that international organizations have updated their exposure limit recommendation in recent years, based on new research whereas the FCC's current standards were based on research prior to 1996. The new international limit had been widely adopted by other countries, including countries in the European Union.

It is important to note that the GAO stated *"the new recommended limit could allow for more RF energy exposure* (emphasis added), but actual exposure depends on a number of factors including how the phone is held during use." Whereas one may argue that new RF exposure limits could be considered germane to smart meters (although RF emissions from smart meters are several orders of magnitude less than the exposure limit), smart meters are not in direct contact with the body.

According to the GAO report, the National Institute of Environmental Health Sciences (NIEHS), a part of the NIH, has a study underway described as "examining the toxicology and carcinogenic effects of RF energy in laboratory animals as part of the National Toxicology Program." The National Toxicology Program is an interagency program whose three core federal agencies are NIEHS, the Centers for Disease Control and Prevention's (CDC)[152] National Institute for Occupational Safety and Health (NIOSH),[153] and the FDA's National Center for Toxicological Research. Total NIH funding for the study was reported to be $25.6 million, and its estimated year of completion is 2015.

According to the GAO report, CDC officials reported that a staff member is collaborating with researchers in seven countries to conduct additional analyses on data collected through the INTERPHONE study to determine whether occupational exposure to RF energy and chemicals was a risk factor for brain cancer.[154]

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150 <http://www.gpo.gov/fdsys/pkg/CFR-2010-title47-vol1/xml/CFR-2010-title47-vol1-part15.xml>.

151 <http://www.gao.gov/assets/600/592901.pdf>.

152 The CDC states that its mission is to collaborate to create the expertise, information, and tools that people and communities need to protect their health – through health promotion, prevention of disease, injury and disability, and preparedness for new health threats.

153 NIOSH states that its mission is to generate new knowledge in the field of occupational safety and health and to transfer that knowledge into practice for the betterment of workers.

154 Ibid.

Other Governmental Jurisdictions and Agencies

City of Naperville, Illinois

In early 2011, some utility customers of Naperville, Illinois expressed concerns regarding the RF EMF emissions from the smart grid equipment that was being deployed for the Naperville Smart Grid Initiative (NSGI). To address the concerns, detailed RF measurements were taken from the smart grid equipment, common household devices, and the ambient Naperville RF EMF environment. Engineers from the Naperville Department of Public Utilities performed the RF testing and compared it to permissible FCC power density specifications.

This emissions testing report issued on November 10, 2011 contains the test scope, overall approach, detailed test procedures, the complete set of test data, explanations, illustrations, and conclusions.[155,156] The comprehensive testing resulted in the following key findings:

- The NSGI smart grid equipment emitted RF power densities that are well below the FCC guidelines;
- Measurements of the smart meter equipment's instantaneous or peak RF power densities ranged between 1% and 3.2% of FCC limits at 20 cm in front of the meter. Note that the measurements observed were from a specially programmed continuously transmitting meter, which would yield inflated results when compared with real world situations;
- Measurements of the smart meter equipment average RF power densities ranged between 0.002% and 0.003% of FCC limits at 20 cm in front of the meter over a 30-minute period.
- The maximum backhaul equipment measured instantaneous or peak RF power density observed was 0.0277% of the FCC limit (measured 20 cm directly in front of the antenna); and
- The smart grid equipment average RF power densities were lower than typical household devices such as microwaves, cell phones, and Wi-Fi routers.

NSGI also issued a brochure[157] to put the RF EMF emissions from its smart meters into perspective:

> "...a person sitting 10 feet in front of their smart meter would have to be there for more than 100 years[158] to receive the same RF energy that they would receive from a 3-minute cell phone[159] call. If a person were sitting inside their home 3 feet from the back of a smart meter, they would have to be there for more than 200 years[158] to receive the same RF energy as they would from a 3-minute cell phone[159] call."

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155 <http://www.naperville.il.us/emplibrary/Smart_Grid/Pilot2-RFEmissionsTesting-SummaryReport.pdf>.
156 <http://www.naperville.il.us/emplibrary/Smart_Grid/Pilot2RFEmissionsTesting-Final.pdf>.
157 <http://www.naperville.il.us/emplibrary/Smart_Grid/SmartMeterandRFCommunications.pdf>.
158 Meter Specifications: Front of meter - Duty Cycle: 0.1%, AMI radio power: 250 mW EIRP, Distance: 10 ft. (305 cm); Behind Meter - Duty Cycle: 0.1%, Distance 3 ft. (91 cm).
159 Cell Phone Specifications: Duty Cycle 45%, Peak Transmitter Power after antenna: 600 mW EIRP, Distance: 1 cm.

Maine Center for Disease Control & Prevention

On October 25th, 2010 a complaint was filed with the Maine Public Utilities Commission (MPUC) focusing on concerns related to the health, safety, and security of smart meters.[160] The Maine Office of the Public Advocate (OPA) called upon the Maine Center for Disease Control & Prevention (Maine CDC) to comment on health concerns related to the wireless communication technology used in the smart meters being installed by Central Maine Power. The Maine CDC received numerous emails and other communications on the issue, and its Public Health Director, Dr. Dora Anne Mills, reviewed the materials sent to her by both opponents and proponents of smart meters. Dr. Mills assembled several Maine CDC staff for further review of the material.

A report was issued[161] by the Maine CDC on November 8, 2010 to the MPUC and OPA. The Maine CDC reported that its review of national and international government or government-affiliated assessments[162] indicated a broad consensus that studies at the time gave no consistent or convincing evidence of a causal relation between RF exposure in the range of frequencies and power used by smart meters and adverse health effects.

According to the Maine CDC's report, they discovered little information in the assessments that spoke directly about the safety of RF exposure from smart meters. There was, however, much discussion about the safety of mobile phones. Mobile phone use represents an RF EMF exposure qualitatively similar to smart meters in range of frequency, but because the power of mobile phones is higher and typical use entails exposure closer to the body, the resulting exposure to RF EMF appeared to be quantitatively much greater than that from smart meters.

Thus, the report stated, it appeared that the lack of any consistent and convincing evidence of a causal relation between RF EMF exposure from mobile phones and adverse health effects would indicate even less concern for potential health effects from use of smart meters.

Subsequent to the investigation, the Maine CDC and others received several letters from people expressing concerns about the review. In order to ensure that OPA, MPUC, and the correspondents had concise responses, Maine CDC grouped the concerns into eight topic areas and compiled a "Frequently Asked Questions" (FAQ) document[163] published on November 29, 2010, which addressed the concerns.

Vermont Department of Health

In January 2012, the Vermont Department of Health measured the RF EMF emissions at active smart meters that had been installed in the town of Colchester by Green Mountain Power. The resulting report[164] stated that readings from the meters verified that the devices emitted only a small fraction of the RF EMF emitted from a typical cell phone, even at very close proximity to the meter. The readings were well below regulatory limits set by the FCC.

The report stated that the measurements taken directly in contact with a smart meter mounted on the exterior wall of a residence ranged from 50 to 140 microwatts per square centimeter (abbreviated $\mu W/cm^2$),

[160] <https://www.maine.gov/dhhs/boh/smart_meters.shtml>.
[161] <https://www.maine.gov/dhhs/boh/documents/Smart_Meters_Maine_CDC_Executive_Summary_11_08_10.pdf>.
[162] <https://www.maine.gov/dhhs/boh/documents/Smart_Meters_Review_of_Government_Resources_11_08_10.pdf>.
[163] <https://www.maine.gov/dhhs/boh/documents/smart-meters-faq.pdf>.
[164] <http://healthvermont.gov/pubs/ph_assessments/radio_frequency_radiation_and_health_smart_meters.pdf>.

compared to the FCC's 610 μW/cm^2 MPE limit for the general population.[165] Measurements taken at distances of three feet or more away from the smart meter were at or near background levels of RF EMF.

Monterey County, California

In late 2010, members of the public that had concerns about potential adverse health effects of smart meters asked the Monterey County Board of Supervisors (the Board) to ban the use of smart meters in Monterey County. On January 11, 2011, the Board requested that the Monterey County Health Department review the literature and produce a report that summarized scientific findings related to smart meters and any potential adverse health effects. In March, 2011 the Health Department issued its report, entitled "Review of Health Issues Related to Smart Meters."[166]

The report's conclusions were as follows:

- Currently available literature indicates that exposure to RF energy from smart meters should be less than that experienced by routine mobile phone use;
- Based on the data available at the time of this review, the current FCC standard provides an adequate factor of safety against known thermally induced health impacts of existing common household electronic devices and smart meters;
- Despite extensive studies, there is no consistency of findings across studies regarding an association between non-thermal adverse health effects and exposure to EMFs from mobile phones;
- Due to various factors, further study is warranted to understand the potential for long-term adverse non-thermal health effects of RF energy from sources such as mobile phones;
- The lower exposure levels likely to be experienced from the deployment of smart meters compared to mobile phones should provide consumers some reassurance that there is a lower potential for adverse non-thermal health effects from the operation of smart meters; and
- Some countries have adopted different exposure limits for EMF or placement of EMF arrays and towers in relation to certain populations based on the Precautionary Principle rather than on scientific certainty.

Australia: Smart Meter Installations in the State of Victoria

In Australia, smart meters and other wireless devices used for communication having frequencies similar to mobile and cordless phones, are regulated by the Australian Communications and Media Authority (ACMA). Emissions from these wireless devices must comply with the ACMA Radiocommunications (Electromagnetic Radiation - Human Exposure) Standard 2003 as amended in 2011.[167] This standard mandates the exposure limits set by Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) which were designed to protect against all known adverse health effects. These exposure limits are described in the document "Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz."[168]

In 2011, the Victorian state government commissioned an independent study by testing laboratory EMC Technologies to determine the actual levels of RF EMF exposures from smart meters, and make sure that the meters complied with the exposure levels set by ARPANSA.

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[165] The micron symbol, μ, is a prefix that represents 10^{-6}, or one-millionth. 1 μW = one-thousandth of one milliwatt (mW).
[166] <http://publicagendas.co.monterey.ca.us/MG97205/AS97224/AS97230/AI99413/DO99416/DO_99416.pdf>.
[167] <http://www.comlaw.gov.au/Details/F2011C00165>.
[168] <http://www.arpansa.gov.au/pubs/rps/rps3.pdf>.

EMF measurement site surveys were conducted on a range of smart meters installed in various types of houses. The EMF measurements were performed on AMI meters installed by the five major utilities in the state of Victoria. The five utilities have joint programs in place to manage these installations, with the end result being three combined deployments. Most measurements were conducted on single AMI installations but also included a group meter installation (with 9 to 12 meters) from each of the three deployments. In these group meter installations, up to six meters were interrogated simultaneously to measure the maximum combined EMF from multiple transmissions.

EMC Technologies tested both types of electromagnetic exposures produced from smart meters - the EMF generated by the operation of a smart meter and RF emissions related to the built-in two-way communications. EMC Technologies found[169] that the maximum RF EMF power density levels were well below the ARPANSA General Public Limit specified by ARPANSA Radiation Protection Standards, even when the meter was forced to transmit continuously (100% duty cycle). More specifically, exposure levels from smart meters inside dwellings ranged from 0.000001% to 0.0113% of ARPANSA's General Public Limit of 450 $\mu W/cm^2$.

The test results also showed that in measurements made at sites with grouped meters, even with a number of meters being requested for meter data upload, the EMF peak field measured did not increase above the level of a single meter transmission. No two meters were transmitting simultaneously. The report concluded that the maximum RF EMF power density from a group meter installation is expected to not be higher than that of a single meter installation.

RF EMF tests were also conducted on various household appliances that emit RF fields – a wireless modem, microwave oven, baby monitor, mobile phone and cordless phone. The RF EMF levels from the meters, even when measured from a foot away, were lower than the levels from these other common household items. The actual EMF levels from a meter, when measured inside the house, were very low compared to the levels from the abovementioned items.

Smart Meters Have Lower ELF EMF Levels than Electromechanical Meters

Extremely Low Frequency electromagnetic fields (ELF EMF) occur at 50Hz in Australia and at 60Hz in the U.S. and are predominantly found in electric energy generation, transmission, and distribution. Unlike the testing performed by the other organizations in this report, the scope of work in the Australian investigation included the measurement of ELF EMF. Tests were conducted on smart meters and on an electromechanical (i.e., rotating disc) electricity meter, as well as an electric blanket, vacuum cleaner, microwave oven, and CRT (Cathode Ray Tube) television.

In the tests, the 50 Hz fields around the smart meter were lower than those from some other common appliances such as vacuum cleaners and microwave ovens. The levels from other appliances such as hairdryers, power tools, induction cookers, fans, and air conditioners would also be much higher.

Finally, the test results showed that ***the fields from the smart meter are slightly lower than the fields from the analog (electromechanical) meter***. The report concluded that the smart meters themselves do not cause any increase in the power line-related EMF levels and that replacement of the older analog meters with AMI meters would reduce ELF EMF exposure.

[169] <http://www.dpi.vic.gov.au/smart-meters/publications/reports-and-consultations/ami-meter-em-field-survey-repor>.

United Kingdom: Health Protection Agency

In April 2012, the Advisory Group on Non-ionising Radiation (AGNIR), an independent advisor to the Health Protection Agency of the UK, produced a document entitled "Health Effects from Radiofrequency Electromagnetic Fields."[170] The Health Protection Agency is an independent organization that was formed by the UK government in 2003 to protect the public from threats to their health from infectious diseases and environmental hazards. According to its website, it does this by providing advice and information to the general public, to health professionals such as doctors and nurses, and to national and local government.[171]

The report starts out by saying that the quantity and quality of research published on the potential health effects of RF field exposure has increased substantially since AGNIR had last reviewed the subject in 2003. While the publication admitted that limitations to the published research still exist and therefore preclude a definitive judgment, the evidence considered did not demonstrate any adverse health effects of RF EMF exposure at levels below the internationally accepted guideline.

The paper stated that while there were possible effects on Electroencephalography (EEG) patterns, they were not conclusively established and that it was unclear whether such effects would have any health consequences.

The AGNIR document also stated that, in regard to RF EMF exposure that was below guideline levels:

- The evidence indicated that it does not cause symptoms;
- RF cannot be detected by people, even by those who considered themselves sensitive to RF fields;
- The evidence pointed toward no material exposure to the risk of cancer although there is little data on risks beyond 15 years from first exposure;
- RF showed no effect on health not related to cancer; and
- There was a lack of convincing evidence that it caused health effects in adults or children.

Health Canada: Safety Code 6

Health Canada[172] is the Canadian federal department responsible for helping its country's people maintain and improve their health, while respecting individual choices and circumstances. Health Canada's document titled "Limits of Human Exposure to Radiofrequency Electromagnetic Fields in the Frequency Range from 3 kHz to 300 GHz"[173,174] is a code that specifies Canada's radiofrequency exposure guidelines, commonly known as "Safety Code 6 (2009)." The guidelines provide recommended best practices for ensuring compliance with the maximum exposure levels for controlled and uncontrolled environments. The Safety Code 6 (2009) standards are similar to the U.S. FCC standards established in 1997.

Regarding MPE, Safety Code 6 states the following:

> "For frequencies from 100 kHz to 300 GHz, tissue heating is the predominant health effect to be avoided. Other proposed non-thermal effects have not been conclusively documented to occur at levels below the threshold where thermal effects arise."

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170 <http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317133827077>.
171 <http://www.hpa.org.uk/AboutTheHPA/>.
172 <http://www.hc-sc.gc.ca/ahc-asc/index-eng.php>.
173 <http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct-eng.php>.
174 <http://www.scribd.com/doc/36604752/Safety-Code-6>.

British Columbia Provincial Health

On December 23, 2011 a statement[175] was prepared at the request of the British Columbia (BC) Provincial Health Officer by Mary McBride, a Distinguished Scientist at the Department of Cancer Control of the BC Cancer Agency (BCCA) in Vancouver, BC. The letter had been approved by Dr. David McLean, Head of Cancer Prevention at the BCCA.

The statement indicated that research evidence does not support a conclusion that RF EMF, whether from cell phones or smart meters, can cause brain tumors in adults. With more than 20 years' cell phone use and limited information on a risk of other cancers, the information that BCCA officials possess generally does not support the notion of cancer. The statement admits that while there is no direct information on children, more studies are underway to address gaps in their understanding of RF EMF and cancer risk. The statement concluded by saying that extensive laboratory research to date has not identified any mechanisms that could function in either adults or children which would lead to an excess risk of tumors in general.

Ontario Province: Ontario Agency for Health Protection and Promotion

On September 16, 2010, the Ontario Province of Canada's Agency for Health Protection and Promotion (Ontario Health Agency) issued a brief paper that cautioned against relying on the results of individual research studies regarding the potential health effects from exposure to RF EMF because inconsistencies or conflicts may exist among the results of other individual studies.

The Ontario Health Agency stated that performing reviews of literature that followed an approach of weighing evidence would be far more useful to inform debate and make sound policy than it would be to merely rely on individual studies.

The Ontario Health Agency pointed to the Royal Society of Canada's (RSC) highly credible review from 1999[176] with updates to the review published as recently as 2009.[177,178] The RSC review called for additional research to follow up on new findings from an additional decade of research and noted that there was still no conclusive evidence of adverse health effects at exposure levels that are below the current Canadian guidelines.

The Ontario Health Agency stated that recently published research demonstrated that Wi-Fi exposure is well within recommended limits and is also only a small fraction (less than 1%) of exposure during the typical use of a cell phone. Because of this, much of the research on possible effects of RF EMF has been focused on exposures from cell phones rather than the lower exposures associated with RF uses such as Wi-Fi, and the focus will continue to be on cell phones. The Ontario Health Agency also stated that public exposure, including school children, to Wi-Fi is far lower than what occurs with cell phone use, and that there is no plausible evidence to date that would indicate that current public exposure to Wi-Fi is causing any adverse health effects.

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[175] <http://www.health.gov.bc.ca/pho/issues.html>.
[176] <http://www.rsc.ca/documents/RFreport-en.pdf>.
[177] <http://www.rsc.ca/documents/expert_panel_radiofrequency_update2.pdf>.
[178] <http://www.ncbi.nlm.nih.gov/pubmed/20183523>.

City of Richmond, British Columbia and Vancouver Coastal Health

The BC Hydro and Power Authority is an electric utility in British Columbia. The company serves 1.8 million customers in most areas of the province and is deploying smart meters. On November 14, 2011, the City of Richmond in British Columbia passed a resolution requesting its Medical Health Officer to "conduct an investigation as to whether smart meters pose a health hazard." The response,[179] dated December 20, 2011 and signed by the BC Health Officer and two officers from Vancouver Coastal Health, concluded that the smart meters installed and used by BC Hydro were not a health hazard. Furthermore, the letter stated that "the transmitters in Smart Meters produce electromagnetic fields at levels significantly lower than the maximum allowed for the Canadian public under Health Canada's Safety Code 6."

Other notable findings of the independent consultant, Planetworks Consulting Corporation include:[180,181]

1. Smart meters are active for only a very short duration at a time;
2. The average power density was 0.3795% of Safety Code 6 for a single smart meter;
3. For a bank of ten smart meters, the average power density was found to be 0.4507% of Safety Code 6 (a range from 0.0015% to 1.6835% of Safety Code 6); and
4. The highest power density value recorded from a bank of ten meters was less than 2% of Safety Code 6 limit, while the average power density for both single and a ten meter bank are less than 0.5% of Safety Code 6.

Note that Safety Code 6 requires the power density at the frequency used by the smart meters to be less than 600 $\mu W/cm^2$ for publicly accessible areas (compared to the FCC's limit of 610 $\mu W/cm^2$). One can see that the power density recorded for a ten meter bank is not ten times that of a single meter, as some may suspect. Instead, the average power density for the ten meter bank was found to be only about 1.2 times that of a single meter, while the maximum value from a bank of ten meters was slightly less than twice the maximum value recorded from a single meter.

Norwegian Institute of Public Health

In spring 2010, an Expert Committee was appointed by the Norwegian Institute of Health and commissioned by the Ministry of Health and Care Services and the Ministry of Transport and Communications. The committee was composed of individuals with expertise in environmental and occupational medicine, biology, physics, metrology, biophysics, biochemistry, epidemiology, and philosophy as well as administration and risk management. In 2012, the committee issued its report.

The committee assessed the health hazards from low-level electromagnetic fields generated by radio transmitters. The Committee evaluated the power of the fields, whether they posed a health risk, the current regulatory practice, and whether the threshold limit values for exposure were observed. A press release from the institute described the report conclusions: [182]

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179 <http://www.health.gov.bc.ca/pho/pdf/vch-response-to-richmond-city-council-re-investigation-into-smart-meters.pdf>.

180 <http://www.bchydro.com/etc/medialib/internet/documents/smi/SMI_SingleSmartMeter.Par.0001.File.SMI-SingleSmartMeter-2011-Oct-11.pdf>.

181 <http://www.bchydro.com/etc/medialib/internet/documents/smi/SMI_MeterBank.Par.0001.File.SMI-MeterBank-2011-Oct-11.pdf>.

182 <http://www.fhi.no/eway/default.aspx?pid=238&trg=MainLeft_5895&MainArea_5811=5895:0:15,2829:1:0:0:::0:0&MainLeft_5895=5825:99168::1:5896:1:::0:0>.

"There is no scientific evidence that low-level electromagnetic field exposure from mobile phones and other transmitting devices causes adverse health effects, according to a report presented by a Norwegian Expert Committee. In addition, the Committee provides advice to authorities about risk management and regulatory practice."

Swedish Council for Working Life and Social Research

The Swedish Council for Working Life and Social Research (FAS) was commissioned by the government of Sweden to monitor issues relating to research into EHS and to document and report on the state of research at regular intervals, starting in 2003. In the executive summary of its 2012 report, FAS stated:[183]

"Extensive research for more than a decade has not detected anything new regarding interaction mechanisms between radiofrequency fields and the human body and has found no evidence for health risks below current exposure guidelines. While absolute certainty can never be achieved, nothing has appeared to suggest that the since long established interaction mechanism of heating would not suffice as basis for health protection."

Health Council of the Netherlands

The Health Council of the Netherlands is an independent scientific advisory body.[184] Its task is to provide the Netherlands government and parliament with advice in the field of public health and health/healthcare research. The agency also addressed EHS in its report, *Electromagnetic Fields: Annual Update 2008*:[185]

"From the good quality scientific data emerges the picture that there is no causal relationship between exposure to radiofrequency electromagnetic fields and the occurrence of symptoms. However, there is a relationship between symptoms and the *assumption* of being exposed and therefore most likely with the risk perception."

World Health Organization

The WHO website contains a wealth of information about EMF, including what it is, links to a database of research citations, national standards, publications, information resources, and meetings. The site also has a link to Germany's EMF-Portal that provides access to research databases.

The organization also hosts the International EMF Project,[186] which was established in 1996 and is open to any WHO Member State government, such as department of health or representatives of other national institutions concerned with radiation protection. The project was established to assess health and environmental effects of exposure to static and time varying electric and magnetic fields in the frequency range 0-300 GHz. The site provides access to 39 ongoing studies, 322 published studies, and 12 studies that have been reported but not published.

There are 54 participating countries and eight international organizations involved in the project. It is fully funded by participating countries and agencies. Its stated key objectives are to:

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[183] <http://www.fas.se/pagefiles/5303/10-y-rf-report.pdf>.
[184] <http://www.gezondheidsraad.nl/en>.
[185] <http://www.gezondheidsraad.nl/sites/default/files/200902.pdf>
[186] <http://www.who.int/peh-emf/project/en/>.

- Provide a coordinated international response to concerns about possible health effects of exposure to EMF;
- Assess the scientific literature and make a status report on health effects;
- Identify gaps in knowledge needing further research to make better health risk assessments;
- Encourage a focused research program in conjunction with funding agencies;
- Incorporate the research results into WHO's Environmental Health Criteria monographs where formal health risk assessments will be made on exposure to EMF;
- Facilitate the development of internationally acceptable standards for EMF exposure;
- Provide information on the management of EMF protection programs for national and other authorities, including monographs on EMF risk perception, communication and management; and
- Provide advice to national authorities, other institutions, the general public and workers, about any hazards resulting from EMF exposure and any needed mitigation measures.

The WHO recognized the following independent scientific institutions for their collaboration:

- U.S. Air Force Research Laboratory, Human Effectiveness Directorate (Brooks Air Force Base, TX);
- Australian Radiation and Nuclear Safety Agency (ARPANSA);
- UK Health Protection Agency - Radiation Protection Division;
- German Federal Office for Radiation Protection (BfS); and
- Institute of Population Health, University of Ottawa, Ontario, Canada.

Some key points are made on the WHO website regarding EMF and health. Among them are the following:

- A wide range of environmental influences causes biological effects. 'Biological effect' does not equal 'health hazard'. Special research is needed to identify and measure health hazards;
- There is no doubt that short-term exposure to very high levels of electromagnetic fields can be harmful to health. Current public concern focuses on possible long-term health effects caused by exposure to electromagnetic fields at levels below those required to trigger acute biological responses;
- Despite extensive research, to date there is no evidence to conclude that exposure to low level electromagnetic fields is harmful to human health;
- The focus of international research is the investigation of possible links between cancer and electromagnetic fields, at power line and radiofrequencies;
- Finding a statistical association between some agent and a specific disease does not mean that the agent caused the disease;
- The absence of health effects could mean that there really are none. However, it could also signify that an existing effect is undetectable with present methods;
- Results of diverse studies (cellular, animal, and epidemiology) must be considered together before drawing conclusions about possible health risks of a suspected environmental hazard. Consistent evidence from these very different types of studies increases the degree of certainty about a true effect; and
- Due to a large safety factor, exposure above the guideline limits is not necessarily harmful to health. Furthermore, time-averaging for high frequency fields and the assumption of maximum coupling for low frequency fields introduce an additional safety margin.

Publications and other specific work outputs from efforts of the WHO, its divisions, and collaborating organizations are noted throughout this report and will not be repeated here.

Comments by Academia on Public Concerns about Wireless Smart Meters

Montréal Polytechnic and McGill University Open Letter

On May 18, 2012, an open letter was issued in support of smart meter technology[187] and signed by 61 scientists and engineers primarily affiliated with one of two universities located in Montréal, Québec, Canada: École Polytechnique de Montréal (Montreal Polytechnic) and McGill University. The few signatories who could be thought to have a conflict of interest through their affiliation with the telecommunications industry or Hydro Québec, the utility in the province deploying more than 3 million smart meters, declared their conflict alongside their names.

In the letter, the Québécois engineers and scientists commented:

> "We believe that the fear of wireless technologies is based primarily on i) a misunderstanding of the nature of radio waves and their interaction with the human body, ii) a misreading of the scientific literature on this subject, and iii) a distrust of local, national and international public health organizations."

The Québec Energy Board, the provincial regulator, took the letter into consideration when rendering its decision[188] to allow Hydro Québec to proceed with its plan to install wireless smart meters in its service territory. The agency stated in its summary[189] (translated from French):

> "The views presented by the public health authorities and the evidence heard by [the Board] on the state of scientific research on the impacts of non-thermal RF on health demonstrate that the emissions from the new generation of smart meters do not present a health risk."

University of Ottawa: RFcom Review Panel Reports

The University of Ottawa's McLaughlin Centre for Population Health Risk Assessment has a project called RFcom[190] that functions as an Internet-based information resource about health effects of wireless technologies. RFcom is managed by a science panel that reviews and reports[191] on the most recent research studies about wireless technology and health from around the world. All studies referenced on its website must meet the following criteria:

- The source must be credible and accountable;
- Material must be peer-reviewed research and data that has been accepted and validated in the Canadian and international communities; and
- All studies must have been carried out by an independent third-party person or organization.

The page contains conclusions and excerpts from reports issued by various organizations from within countries and international bodies including Canada, Denmark, the EC, Finland, France, Germany, Iceland, Netherlands, Norway, Spain, Sweden, the UK, and the U.S. These excerpts overwhelmingly indicate that there is no

[187] <http://www.polymtl.ca/phys/doc/Lettre_ouverte_de_scientifiques_quebecois_les_compteurs_intelligents.pdf>.
[188] <http://internet.regie-energie.qc.ca/Depot/Projets/111/Documents/R-3770-2011-A-0163-DEC-DEC-2012_10_05.pdf>.
[189] <http://internet.regie-energie.qc.ca/Depot/Projets/111/Documents/R-3770-2011-A-0164-DEC-DEC-2012_10_05.PDF>.
[190] <http://www.rfcom.ca/welcome/index.shtml>.
[191] <http://www.rfcom.ca/panel/index.shtml>.

conclusive evidence to support many of the assertions smart meter opponents are making about the harms of RF EMF exposure and negative health outcomes.

Other Issues

Potential for Interference with Medical Devices

Some people have expressed concern that signals from smart meters could interfere with the operation of implanted electronic devices such as pacemakers or other medical equipment. According to the FCC, because they are electronic devices, there is a potential for such devices to be susceptible to electromagnetic signals that could cause them to malfunction. The FCC stated[192] that there have been anecdotal claims of such effects in the past which involved emissions from microwave ovens but that it has never been shown that the RF energy from a properly operating microwave oven is strong enough to cause such interference. The FCC also stated that the FDA requires pacemaker manufacturers to test their devices for susceptibility to electromagnetic interference (EMI) over a wide range of frequencies and to submit the results as a prerequisite for market approval. Electromagnetic shielding has been incorporated into the design of modern pacemakers to prevent RF signals from interfering with the electronic circuitry in the pacemaker.[193]

Both the FCC and FDA[194] refer to studies which have shown that mobile phones can interfere with implanted cardiac pacemakers if a phone is used in close proximity (within about eight inches) of a pacemaker. Such interference appears to be limited to older pacemakers which may no longer be in use. The agencies recommend that those with pacemakers avoid placing a phone in a pocket close to the location of their pacemaker or putting the phone near the pacemaker location when using the phone.

One of the studies to which the FCC and FDA refer was published in The New England Journal of Medicine[195] in which a total of 980 patients were tested. Seven hundred twenty-five patients were tested with six telephones and 255 were tested with five telephones, providing a total of 5625 tests. Ninety-two tests were eliminated because of incomplete data. Thus, statistical analyses were based on 5533 tests. The study concluded that no interference was observed in any pacemaker at base line. The study stated that while abnormalities of pacing were observed at base line in 23 of 976 patients (2.4%) during testing, evidence of these abnormalities was not considered to be due to interference.

Further, ANSI and the Association for the Advancement of Medical Instrumentation (AAMI) have devised a standard[196] known as ANSI/AAMI PC69:2007 which establishes electromagnetic compatibility test protocols for active implantable cardiovascular devices. The standard is intended for manufacturers of implantable medical devices and consultants who test implantable devices. It specifies test methods related to interference frequencies and their potential effects on implantable devices such as cardiac pacemakers and internal defibrillators. It also requires disclosure of a device's performance issues in the presence of EM emitters where appropriate and provides manufacturers of EM emitters with information about the level of immunity to be expected from active implantable cardiovascular devices.

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[192] <http://transition.fcc.gov/oet/rfsafety/rf-faqs.html#Q22>.
[193] <http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf>.
[194] <http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/HomeBusinessandEntertainment/CellPhones/ucm116311.htm>.
[195] <http://www.nejm.org/doi/pdf/10.1056/NEJM199705223362101>.
[196] <http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2FAAMI+PC69%3A2007>.

Claims of Electromagnetic Hypersensitivity

World Health Organization

The WHO is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries, and monitoring and assessing health trends.[197]

In December 2005, the WHO International EMF Project created a fact sheet on electromagnetic fields and public health in order to address EHS.[198] The fact sheet describes what was known about the condition, and it provided information for helping people with such symptoms. The information was based on a WHO Workshop on Electrical Hypersensitivity (Prague, Czech Republic, 2004),[199,200] an international conference on EMF and non-specific health symptoms (COST 244bis, 1998),[201] a European Commission report (Bergqvist and Vogel, 1997),[202] and reviews of the literature.

The fact sheet stated that EHS is characterized by a range of non-specific symptoms that lack apparent toxicological or physiological basis or independent verification and that it differs from individual to individual.[203] The sheet stated that the symptoms are certainly real and can vary widely in their severity, and they can be a disabling problem for the affected individual.

The WHO document noted that a number of scientific studies had been conducted where EHS individuals were exposed to EMF similar to what they had attributed to the cause of their symptoms. The aim of the studies was to elicit symptoms under controlled laboratory conditions. The WHO fact sheet stated that the majority of studies indicated that EHS individuals could not detect EMF exposure any more accurately than non-EHS individuals. Double-blind studies which were well-controlled and well-conducted had shown that symptoms were not correlated with EMF exposure. Therefore, it stated, EHS has no clear diagnostic criteria, and there is no scientific basis to link EHS symptoms to EMF exposure.

It had been suggested that symptoms experienced by some EHS individuals might arise from environmental factors unrelated to EMF including flicker from fluorescent lights, glare and other visual problems with video displays, and poor ergonomic design of computer workstations. The fact sheet stated that other factors that may play a role included poor indoor air quality or stress in the workplace or living environment.

Finally, there were some indications that the symptoms may be due to pre-existing psychiatric conditions as well as stress reactions that were a result of worrying about EMF health effects, rather than EMF exposure itself. It explained that EHS is not a medical diagnosis, nor is it clear that it represents a single medical problem. Thus, some medical experts described EHS as an example of a psychogenic illness. A psychogenic illness is a constellation of symptoms suggestive of organic illness, but without an identifiable cause, that

[197] <http://www.who.int/about/en/>.
[198] <http://www.who.int/mediacentre/factsheets/fs296/en/index.html>.
[199] <http://www.who.int/peh-emf/meetings/hypersensitivity_prague2004/en/index.html>.
[200] <http://ihcp.jrc.ec.europa.eu/our_activities/public-health/exposure_health_impact_met/emf-net/docs/publications/WHO_EMF-NET%20Book.pdf>.
[201] <ftp://ftp.cordis.europa.eu/pub/cost/docs/244bisfinalreport.pdf>.
[202] <https://gupea.ub.gu.se/bitstream/2077/4156/1/ah1997_19.pdf>.
[203] Idiopathic Environmental Intolerance attributed to Electromagnetic Fields (IEI-EMF) is a term that is being increasingly used to describe this disorder.

occurs between two or more people *who share beliefs about those symptoms* (emphasis added). Psychogenic illnesses have made headlines when they have become manifest as a widespread phenomenon.[204]

King's College London: Systematic Review of Provocation Studies for EHS

King's College London's School of Medicine is one of the UK's most renowned centers for medical research and teaching. It has three central London hospital campuses, and its research portfolio is closely aligned to its National Health Service partners. The school has ten research divisions and it hosts 12 externally awarded and funded specialist centers.[205]

In 2005, school researchers performed meta-analyses[206] to identify relevant blind or double-blind EMF provocation studies.[207] According to the researchers, thirty-one experiments testing 725 EHS participants were identified.[208] Out of the 31 studies, 24 found no evidence to support the existence of a biophysical hypersensitivity, whereas seven reported some supporting evidence. For two of these seven studies, the same research groups subsequently tried to replicate their findings but failed. In three of the seven studies, the positive results appeared to be statistical artifacts. The remaining two studies produced mutually incompatible results.

According to the King's College researchers, the meta-analyses found no evidence of an improved ability to detect EMF in EHS participants. They concluded that the symptoms described by EHS sufferers can be severe and are sometimes disabling but that it had proven difficult to demonstrate under blind conditions that exposure to EMF could trigger symptoms. The researchers stated that analyses suggested that EHS was unrelated to the presence of EMF. The researchers stated that more research into this phenomenon was required.

In 2009, a team of researchers from King's College performed an updated systematic review of provocation studies for EMF.[209] The researchers performed an extensive literature search and identified 15 new experiments. This time, 46 blind or double-blind provocation studies were analyzed in total, involving 1175 EHS volunteers to determine whether exposure to EMF is responsible for triggering symptoms in EHS individuals. The researchers determined that no robust evidence could be found to support the theory.

However, the researchers stated, the studies included in the review did support the role of the nocebo effect in triggering acute symptoms in EHS sufferers. A nocebo response is an unpleasant, harmful, or undesirable effect(s) that a subject manifests, typically after receiving a placebo. The nocebo effect has drawn increased interest from the medical community because studies show that patients are highly receptive to negative suggestion.[210]

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[204] <http://www.cmaj.ca/content/172/1/36.full.pdf>.
[205] <http://www.kcl.ac.uk/medicine/about/index.aspx>.
[206] A meta-analysis is a systematic method of evaluating statistical data based on results of several independent studies of the same problem.
[207] A provocation study is a form of medical clinical trial whereby participants are exposed to a substance or situation that is claimed to provoke a response or to a sham substance or device that should provoke no response.
[208] <http://www.aefu.ch/typo3/fileadmin/user_upload/aefu-data/b_documents/themen/elektrosmog/Position_Forschungstand/rubin_Elektrosensib.Provokationsstudie05.pdf>.
[209] <http://www.essex.ac.uk/psychology/EHS/Rubin%20et%20al%20REVIEW_2009.pdf>.
[210] <http://www.aerzteblatt.de/pdf.asp?id=127210>.

Recent Court Decision Regarding Claim of EHS

In a recent court decision in New Mexico, the plaintiff claimed to have health problems triggered by exposure to EMF generated by his neighbor's electrical equipment (e.g. cordless telephones, computer equipment, dimmer switches, and Wi-Fi routers and modems). The court concluded that EHS is not a scientifically recognized disease, excluded the testimony of the plaintiff's two experts, and dismissed the case.[211,212]

Use of EMF as a Weapon

Some opponents of smart meters have spoken of two kinds of weapons being developed by military organizations such as the U.S. Department of Defense[213] or by other countries. Because weapons are typically associated with causing bodily harm or death, they are addressed in this paper.

Both kinds of weapons utilize electromagnetic radiation, but they use it differently and have different end goals. The first kind of weapon to be discussed has been demonstrated to the public. The existence of the second kind of weapon seems to be more speculative.

Directed Energy Weapons

The first type of weapon is known as a directed energy weapon which delivers energy to a target. The target can be humans, electronic equipment, or other military targets, depending on the technology employed. It can be used for purposes other than to destroy a target or kill soldiers. For example, the Active Denial System (ADS) is a weapon under development that is intended for use against humans. It is non-lethal and designed for area denial,[214] perimeter security, and crowd control. The device is mountable on a small armored vehicle.

The ADS works by firing a narrow, high-powered beam of 95 GHz waves at a human target. The energy from an ADS works on a similar principle as a microwave oven, exciting the water and fat molecules in the skin, and instantly heating them (dielectric effect).

How deep a radio wave can penetrate an object depends upon the wave's frequency. The high frequency waves used in ADS penetrate 1/64th of an inch into the top layers of the subject's skin. At that skin depth lie "nociceptors" which are nerve endings sensitive to heat. *Wired* magazine indicated that documents it acquired from the government stated that 83% of the energy impacting the target was instantly absorbed by the top layer of the skin.[215] Being hit by the energy from the ADS gives the victim a sensation of his entire body being exposed to intense heat but without injury taking place. The pain reflex makes the targeted person instinctively pull away in less than a second. To avoid potential trauma to the subject, the trigger on the device only allows the weapon to be fired for three seconds.

The *Wired* article states that the energy delivered to a target is 12 joules per square centimeter.[216] The ADS delivers those 12 joules of energy over a three-second period, which is equivalent to delivering four watts (4000 mW) of power each second per square centimeter.

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[211] Firstenberg v. Monribot and Leith, No. D-101-CV-2010-00029, New Mexico 1st Dist, Santa Fe County, Sept 18, 2012.

[212] <http://www.casewatch.org/civil/firstenburg/dismissal_order.pdf>.

[213] <http://jnlwp.defense.gov/>.

[214] Area denial weapon is used to prevent an adversary from occupying or traversing an area of land. Land mines and punji sticks are examples of denial weapons, albeit ones which are potentially lethal.

[215] <http://www.wired.com/dangerroom/2012/03/pain-ray-shot/>.

[216] <http://www.wired.com/science/discoveries/news/2006/12/72134?currentPage=all>.

The Human Effects Advisory Panel of Penn State concluded that ADS is a non-lethal weapon that has a high probability of effectiveness with a low probability of injury.[217] The limit of damage was the occurrence of pea-sized blisters in less than 0.1% of the exposures (6 of 10,000 exposures).

While this information may be interesting, the existence of such a weapon cannot be credibly used as an argument against employing RF communication devices because:

- The ADS is specifically designed as a weapon, not communications equipment;
- The ADS is very dissimilar to a smart meter because it uses a frequency 100 times higher than the 902-928 MHz band used by the meters' communication module;
- The ADS has an enormous power output. It delivers more than 3.5 million times the instantaneous peak energy of a smart meter radio module; and[218]
- Although the ADS is considered a weapon, it does not cause injury, only brief discomfort.

Cold War Studies on Behavior Modification and Human Vulnerability

The second type of weapon mentioned by opponents of wireless communications technology does not seem to have been displayed or demonstrated as a functioning device. Instead, some people who have provided material to the PUCT or appeared before it, the Texas Senate, or regulatory bodies in other jurisdictions have referred to research that had been performed mostly by Soviet Bloc countries during the Cold War, especially the Soviet Union.

Opponents of wireless technology have pointed to unclassified documents[219,220] produced by the U.S. Defense Intelligence Agency (DIA)[221] during the early 1970s as evidence that the Soviet Union was doing research on EMF along with exploring subject matter that was more unconventional. The stated purpose of the DIA disseminating this information was for preparedness and to develop countermeasures. It may be speculative to assume that more detailed information existed but was kept classified. We are limited to the available documents.

The documents summarize the known research in which the Soviet Union was involved regarding human vulnerabilities to various environmental conditions and behavior modification through the application of certain stimuli. Of particular interest to opponents of wireless technology are the studies performed to determine human vulnerability to EMF and how it could be used to alter a subject's behavior. These weapons were intended for use against an individual rather than a group.

One may be intrigued by the fact that in addition to the cited studies on the effects of EMF on living organisms, the documents also discuss psychology and parapsychology research. For example, some experiments involved telepathic communication, mind altering drugs, sensory deprivation, psychokinesis, and many other

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[217] <http://jnlwp.defense.gov/pdf/heap.pdf>.

[218] ADS exposure: 12 joules/cm^2 delivered over a three-second burst = 4,000 mW/cm^2. Smart meter exposure: 0.0011346 mW/cm^2 instantaneous peak field exposure in front of meter, at a distance of three feet, assuming a 100% duty cycle. Calculated from Table 9-5 of EPRI Report "An Investigation of Radiofrequency Fields Associated with the Itron Smart Meter," Page 9-15.

[219] <http://science.discovery.com/tv/dark-matters/documents/pdf/controlled-offensive-behavior.pdf>.

[220] <http://www.magdahavas.com/wordpress/wp-content/uploads/2011/02/BIOLOGICAL_EFFECTS_OF_ELECTROMAGNETIC_RADIATION-RADIOWAVES_AND_MICROWAVES-EURASIAN_COMMUNIST_COUNTRIES.pdf>.

[221] Although the specific focus of the DIA has changed over the years, its central function has been to provide military intelligence to various facets of the U.S. military community.

seemingly strange topics. The fact that EMF research is mentioned in the same context as these arcane studies may lead some readers to errantly conclude that EMF is equally mysterious.

While some may find the material offered in the documents regarding EMF experiments on animal subjects interesting and germane to the topic of this report, several caveats are in order:

- The material is unclassified (compared to declassified) and offers nothing new – it is a part of the extensive body of knowledge on EMF. Despite the Cold War, scientific research was published and shared between the two sides;
- The material is old and may be out of date;
- The descriptions of the research are only abstracts, providing very little detail;
- The citations are of individual studies. Other studies may have conclusions that are incompatible; and
- Some material sourced from Soviet Bloc nations may be of questionable value. The results could have been subject to the political environment of the era.

The Soviet Bloc was not alone in conducting such research. The U.S. Central Intelligence Agency had also conducted behavioral modification experiments from the 1950s until the early 1970s. These experiments, collectively known as Project MKULTRA, relied on mind-altering drugs, hypnosis, sleep deprivation and other forms of harassment.[222]

Claims have been made that the work done under Project MKULTRA may have been used in conjunction with EMF to create "psychotronic weaponry"[223] in the form of "Silent Sound" or "Voice to Skull" technology. Voice to Skull technology is based on what is known as the microwave auditory effect or "microwave hearing." Microwave hearing is caused by using pulsed EMF in the microwave frequency band to induce audible clicks or sounds described as buzzing, hissing, or knocking. The cause is thought to be thermoelastic expansion of portions of the ear.[224] The sounds are generated directly inside the human head without the need of any receiving electronic device and are not audible to other people, even if they are nearby. If the signal is modulated,[225] whole words can be produced.

The idea behind this technology was that the spoken words of a hypnotist could be conveyed through microwave hearing into an unknowing person's head. This would allow the hypnotist to control the actions of the targeted individual's subconscious mind. Some have speculated about another possibility - that a targeted individual who heard voices inside his head would be distressed over the notion of going insane or being viewed as such.

The microwave auditory effect was first reported by persons working in the vicinity of radar transponders during World War II. The effect was later discovered to be inducible by frequencies higher in the electromagnetic spectrum. American neuroscientist Allan H. Frey studied this phenomenon and first published information[226] on the nature of the microwave auditory effect.[227] At least one patent has been issued for "Voice to Skull" technology based on the material in Frey's studies - U.S. Patent 4,877,027.[228] Note that several

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[222] <http://upload.wikimedia.org/wikipedia/commons/0/01/ProjectMKULTRA_Senate_Report.pdf>.
[223] A psychotronic weapon is an alleged type of mind control device.
[224] <http://www.ncbi.nlm.nih.gov/pubmed/17495664>.
[225] In telecommunications, modulation is the process of varying one or more properties of a high-frequency periodic waveform: amplitude, phase, or frequency. The effective result is piggybacking a signal on top of the RF EMF.
[226] <http://jap.physiology.org/content/17/4/689>.
[227] <http://www.slavery.org.uk/Bioeffects_of_Selected_Non-Lethal_Weapons.pdf>.
[228] <http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=4&f=G&l=50&co1=AND&d=PTXT&s1=4,877,027&OS=4,877,027&RS=4,877,027>.

criteria must be met in order for a U.S. patent to be issued, but the existence of a functional device is not one of those criteria. There is no credible evidence to suggest that such a device exists.

While this may be an interesting phenomenon, it is not applicable to smart meters because:

- The energy intensity required to accomplish the microwave auditory effect would be greater than the output capability of the radio module in a smart meter – perhaps even above MPE levels;
- The frequencies involved (higher microwave bands) are outside the range emitted by smart meters;
- EMF is directional in nature. A device intended to produce these sounds would require a transmitting antenna that optimized this directionality, and the emitted energy would have to be aimed directly at a person's head. Studies performed by EPRI of emission patterns from smart meters show the transmitting antenna in a smart meter directs most of its RF energy outward, away from the wall on which it is mounted. The RF energy would be greatly attenuated inside the building. Also, meter antennas are not aimed at people's heads;
- The existence of psychotronic weapons as described above is merely speculative; and
- Smart meters are designed to measure a customer's overall electricity usage and deliver that data to the utility. They may also offer a limited set of information to an end user if he desires. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions.

Other Material

Critics of wireless technology have called attention to various materials in order to further claims about adverse health effects of exposure to EMF, including non-thermal effects. Some people have made assertions that this material has been forgotten, hidden, or suppressed. One example of a paper that opponents of wireless technology characterize as neglected was originally written for the Naval Medical Research Institute (NMRI) in 1971 and updated six months later. The document is "Bibliography of Reported Biological Phenomena ('Effects') and Clinical Manifestations Attributed to Microwave and Radio-frequency Radiation, MF12.524.015-0004B, Report No 2 Revised."[229]

The first chapter of the document provides an outline of biological phenomena that had been reported in individual studies of biological exposure to microwave or RF radiation. The more than 120 reported phenomena are placed into 17 categories such as "changes in physiologic function," "central nervous system effects," "psychological disorders," and "endocrine gland changes." The remainder of the document makes up the bulk of its content and is a bibliography that identifies 2311 research papers, the oldest of which dates from 1925 and the most recent from 1972. The author stated that the paper was created to provide a listing of studies that may be "needed in the formulation and appraisal of criteria and limits of human exposure to non-ionizing radiation, and in the planning and conduct of future research."

The author noted that a few citations were of marginal and/or peripheral relationship but were nonetheless included so a reader could judge the applicability to his individual research needs. The author draws no conclusions and admits that the screening of the entries was limited to relevance of the topic, not the quality of the studies or the validity of their results:

> "Note: These effects are listed without comment or endorsement since the literature abounds with conflicting reports. In some cases the basis for reporting an "effect" was a single or a non-statistical observation, which may have been drawn from a poorly conceived (and poorly executed) experiment."

229 <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=AD0750271>.

While there may be people who believe that the listing in the NMRI paper of purported effects resulting from exposure to EMF reveals damning evidence of harm, the document is limited in value for the following reasons:

- The paper merely compiles a list of reported effects without assessing their validity or prevalence;
- The document is primarily intended as a bibliography, citing research performed;
- The material does not offer abstracts for the cited studies (no findings are given);
- The report does not provide conclusions or determine causality - no meta-analysis was performed;
- The list is no longer comprehensive - it is over 40 years old (research dates from 1925 – 1972); and
- The cited studies do not yield any new information - they have been a part of the extensive body of knowledge on RF EMF for many years.

Further, the stated purpose of the NMRI paper was for planning and to conduct future research. When the FCC established its exposure standards in 1996, the results of the studies listed in the bibliography of the paper had been available for decades, and the standards took this research into consideration. Research on the biological effects of EMF has continued and will continue for the foreseeable future.

Conclusion

RF EMF, a form of non-ionizing radiation, has been utilized for nearly a century to broadcast radio and television programs and for many other types of telecommunication. Smart meters, an upgrade to our electrical infrastructure, emit EMF at only low intensity and within a narrow part of the RF band, close to the ranges where UHF TV, cordless phones, and cellular phones operate.

Decades of scientific research have not provided any proven or unambiguous biological effects from exposure to low-level radio frequency signals. Further, after performing a review of all available material, Staff found no credible evidence to suggest that smart meters emit harmful amounts of RF EMF.

At higher intensities, RF EMF can heat living tissue. As a result, the FCC established a more restrictive MPE for the general population that is 2% of the level where thermal effects are known to occur. This lower limit was established for the general population because exposure typically results from a situation that the recipient cannot control and a maximum possible time of exposure (24 hours per day) was presumed.

For decades, much scientific research has been performed to investigate the potential health effects of exposure to many kinds of EMF, including RF. Governmental health agencies from around the world, including but not limited to the U.S., Canada, the UK, and Australia, as well as academic institutions and other researchers, have stated that there are no known *non-thermal* effects from exposure to RF EMF. In other words, tissue heating is the only known risk of exposure to RF EMF. Nonetheless, substantial medical research on any potential non-thermal effects of non-ionizing radiation will continue in the future, and will include studies on emissions that fall into the RF bands.

Those concerned about health will often refer to the results of an individual research study or sometimes several studies to draw conclusions. It is important to use great caution when relying on the results of individual research studies because other studies may have inconsistent or even conflicting results. One must also consider that not all studies hold equal value in the scientific community; all research has some amount of inherent bias, and some studies arguably have flaws or lack scientific rigor.

EPRI, Naperville, the Vermont Department of Health, the Victorian State Government of Australia, and the City of Richmond in British Columbia, Canada have conducted investigations of smart meter RF EMF, and found that smart meters complied with the governmental exposure limits in their respective jurisdictions.

When measurements were taken at relative close proximity to smart meters or groups of smart meters, the RF EMF emissions were several orders of magnitude below the established exposure limits. It is important to note that increasing distance will decrease the intensity of an EM field by the square of the distance (i.e. decrease exponentially).

In addition to distance, in-residence exposure to emissions is further decreased by:

- Shielding of the meter enclosure;
- Building construction materials;
- Antenna orientation of the meter; and
- Meter duty cycle – data is transmitted only 1 - 5% of the time.

Some smart meter opponents have raised the concern that the meters may interfere with other electronic devices including implantable medical devices. Smart meters communicate using unlicensed spectrum. The FCC has mitigated the potential for interference among electronic devices operating in unlicensed spectrum by requiring these devices to be tested and certified as compliant with its rules before they can be marketed. Financial penalties can be assessed if one does not comply with the appropriate FCC equipment authorization procedure. Medical devices must also comply with EMI standards.

Some opponents of smart meters have raised the idea of electromagnetic hypersensitivity and cite anecdotes of having witnessed or experienced various afflictions. After reviewing a substantial body of evidence, the WHO concluded that there was no scientific basis to link EHS symptoms to EMF exposure. It has suggested that symptoms experienced by some individuals described as EHS might arise from environmental factors unrelated to EMF or that the symptoms may be due to pre-existing psychiatric conditions or stress reactions resulting from worrying about EMF health effects, rather than the EMF exposure itself. Further, scientific studies show that people who are ill are highly receptive to negative suggestion and may demonstrate a "nocebo response" as a result of these suggestions.

The notion that EMF can be used as a weapon to cause pain, disrupt thought, or alter or control human behavior might be interesting to some people, but smart meters do not have the capabilities to do these things. First, the output energy from a smart meter radio module is miniscule. Second, the module does not transmit at frequencies near those used in directed energy weapons systems or which have been purportedly used in physiological or psychological experiments. Further, smart meters are designed to measure a customer's overall electricity usage and deliver that data to the utility. A meter may also offer a limited set of information to an end user if he desires. Smart meters are not intended for, are not designed to, and do not have the capability to harm an individual or direct a person's thoughts or actions.

A large number of scientific studies regarding the biological effects of EMF on living organisms have been performed over a period of at least seven decades. These studies are part of an extensive body of human knowledge on the subject, and safety standards have been devised based on the body of knowledge. One must be cautious when individuals make claims about research being suppressed, and when individual studies are cited as evidence that hazards or illnesses are being ignored. Other studies may produce conflicting results. One must be cognizant of what adherence to scientific principles entails and how to decipher research. Laymen often may not recognize poorly executed studies, or they can misinterpret the results of properly conducted scientific research. Either of these circumstances may lead a casual observer to draw errant conclusions.

Acronyms and Abbreviations

AAEM	American Academy of Environmental Medicine
AAMI	Association for the Advancement of Medical Instrumentation
ABEM	American Board of Environmental Medicine
ACMA	Australian Communications and Media Authority
AEIC	Association of Edison Illuminating Companies
AGNIR	Advisory Group on Non-ionising Radiation
AM	Amplitude Modulated
ANSI	American National Standards Institute
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BC	British Columbia
BCCA	BC Cancer Agency
BfS	German Federal Office for Radiation Protection
CCST	California Council on Science and Technology
CDC	Center for Disease Control and Prevention
cm	centimeter (0.01 meter)
CPUC	California Public Utilities Commission
CRT	Cathode Ray Tube
DDT	dichlorodiphenyltrichloroethane
EA	Equipment Authorizations
EC	European Commission
EEG	Electroencephalography
EEI	Edison Electric Institute
EHS	Electromagnetic Hypersensitivity
EIRP	Effective Isotropic Radiated Power
ELF	EMF Extremely Low Frequency electromagnetic fields
EM	Electromagnetic
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EMR	Electromagnetic Radiation
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERP	Effective Radiated Power
EU	European Union
eV	Electron Volt
FAQ	Frequently Asked Questions
FAS	Swedish Council for Working Life and Social Research
FCC	Federal Communications Commission
FDA	U.S. Food and Drug Administration
FM	Frequency Modulated
GAO	U.S. Government Accountability Office
GHz	Gigahertz (1 billion hertz)

GPS	Global Positioning System
HAN	Home Area Network
HHS	U.S. Department of Health and Human Services
Hz	Hertz (cycles per second)
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
kg	kilogram (1000 grams)
kHz	kilohertz (1000 hertz)
LBNL	Lawrence Berkeley National Laboratory
Maine CDC	Maine Center for Disease Control & Prevention
MHz	megahertz (1 million hertz)
MPE	Maximum Permissible Exposure
MPSC	Michigan Public Service Commission
MPUC	Maine Public Utilities Commission
mW	milliwatt (0.001 watts)
NCI	National Cancer Institute
NCRP	National Council on Radiation Protection and Measurements
NEMA	National Electrical Manufacturers Association
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NMRI	Naval Medical Research Institute
NSGI	Naperville Smart Grid Initiative
OET	FCC Office of Engineering and Technologies
OPA	Maine Office of the Public Advocate
OSHA	U.S. Occupational Safety and Health Administration
PG&E	Pacific Gas & Electric
PUCT	Public Utility Commission of Texas
RF	Radio Frequency
RF EMF	Radio Frequency Electromagnetic Field
RSC	Royal Society of Canada
SAR	Specific Absorption Rate
SGTAP	Smart Grid Technical Advisory Project
TV	Television
UHF	Ultra-high Frequency
UK	United Kingdom
U.S.	United States of America
UTC	Utilities Telecom Council
VHF	Very High Frequency
W	Watt
WHO	World Health Organization
μW	microwatt (1 millionth of a watt)
$\mu W/cm^2$	microwatts per square centimeter

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VERMONT
DEPARTMENT OF HEALTH

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Radio Frequency Radiation and Health: Smart Meters

Electric utilities are working to install advanced metering technology known as "smart meters" that use radio signals to communicate electricity demand through mobile telecommunications. The signals that are used – radio frequency radiation or RFR – are the same type as those used for radio and TV broadcasting for many years. Microwave ovens, radar and wi-fi devices also emit RFR, but today mobile telephones are the most common source of exposure to RFR.

There is little scientific data specific to smart meters. However, the RFR from smart meters and mobile telephones are nearly identical, so investigations on potential health effects from mobile telephones can be used to estimate potential health effects from smart meters. Smart meters, according to both mathematical modeling and field tests, emit RFR at very low levels, lower than mobile telephones. The current health protection standards established for mobile telephones in the U.S. and in most other countries around the world are generally accepted as sufficient to prevent health effects from smart meters.

In January 2012, the Vermont Department of Health made actual measurements at active smart meters installed by Green Mountain Power in Colchester. The readings from these devices verify that they emit no more than a small fraction of the RFR emitted from a wireless phone, even at very close proximity to the meter, and are well below regulatory limits set by the Federal Communications Commission (FCC).

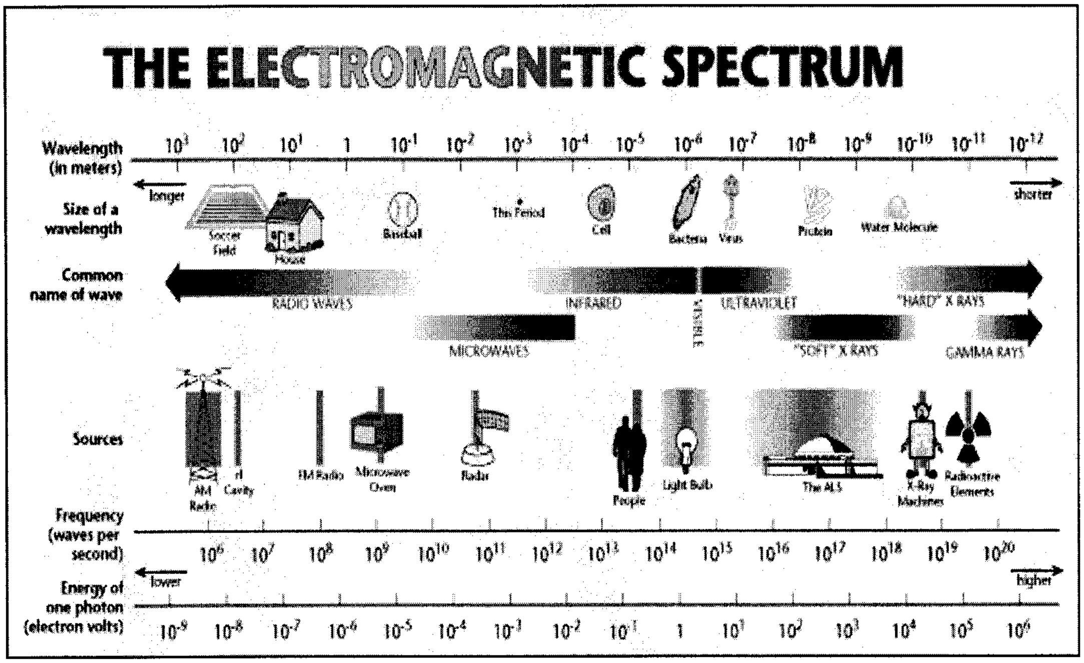
For example, measurements taken directly in contact with a smart meter on the exterior wall of a residence ranged from 50 to 140 $\mu W/cm^2$ compared to the FCC's maximum permissible exposure limit of 610 $\mu W/cm^2$ for a member of the public. Measurements at distances of three feet or more away from the smart meter were at or near background. (See *Smart Meter Measurements in Vermont*, p. 4 for full discussion.)

After extensive review of the scientific literature available to date and current FCC regulatory health protection standards, we agree with the opinion of experts:

- The thermal health effects of RFR are well understood, and are the current basis for regulatory exposure limits. These limits are sufficient to prevent thermal health effects.

- Non-thermal health effects have been widely studied, but are still theoretical and have not been recognized by experts as a basis for changing regulatory exposure limits.

The Vermont Department of Health has concluded that the current regulatory standards for RFR from smart meters are sufficient to protect public health.



SOURCE: *Lawrence Berkeley National Laboratory*

Regulation of Radio Frequency Radiation

Exposure to RFR from devices is generally regulated by the Federal Communications Commission (FCC), which licenses entities that use radio frequencies. The FCC has taken the recommendations of the National Council on Radiation Protection and Measurements (NCRP) and the Institute of Electrical and Electronics Engineers (IEEE) to put forth maximum permissible exposure (MPE) limits for radio frequency radiation as generated by devices using the frequencies it licenses. The MPEs are based on preventing thermal effects from RFR. The NCRP guidelines and the IEEE standard are formulated with knowledge and analysis of the scientific literature regarding non-thermal effects of RFR. Neither the NCRP nor the IEEE considered the evidence from epidemiological and laboratory studies of non-thermal effects sufficient for guidance or standard-setting.

The FCC maximum permissible exposure limits are established to prevent thermal effects of RFR using units of power density. Power density is measured in units of watts per square meter (W/m^2), milliwatts per square centimeter (mW/cm^2) or microwatts per square centimeter ($\mu W/cm^2$). The MPE varies over the range of radio frequencies because the human body absorbs some radio frequencies more than others. Whatever the frequency, exposures less than the MPE will maintain the thermal energy absorption in the human body well below any hazardous level.

Basis of the Regulatory Standards

The human body is capable of absorbing a range of thermal energy changes with physiological cooling mechanisms. However, at certain rates of heating, the body cannot compensate. The MPE limits are designed to prevent heating of human tissues beyond this capacity and are derived from what are called specific absorption rates. MPE limits are set to ensure that the heating of our bodies is at a rate that our bodies can handle without risk of adverse effects. A wide safety margin is provided. In particular, the lowest specific absorption rate found in laboratory animals and human test subjects to cause adverse biological effects is 4.0 watts of heating per kilogram of tissue as averaged over the entire mass of the body. To provide a safety margin, the MPE limits for workers are based on 0.4 watts per kilogram (W/kg), which is 10 times lower than this lowest observable adverse effect level. The public MPE limit is based on a specific absorption rate of no more than 0.08 W/kg because it is assumed that members of the public may be exposed 168 hours per week rather than the 40 hours per week a worker might be maximally exposed.

The MPE limit is designed to prevent thermal effects, and scientific panels reviewed hundreds of research studies to arrive at a consensus. The MPE limit is not based on any non-thermal effects. Nevertheless, the committees making the recommendations for the MPE limits evaluated health effects and other research that focused on possible non-thermal effects. Members of NCRP Committee 53, which prepared NCRP Report 86. *Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields* considered numerous laboratory studies of cells, whole animals and humans as well as numerous epidemiological studies of human populations exposed in occupational and public settings which sought to quantify an association of RFR exposure with effects that are not related to temperature change. The IEEE Standards Coordinating Committee 28 did the same for its IEEE C95.1-1999 publication *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.*

The 1986 NCRP publication devoted significantly less attention to non-thermal effects than did the 1999 IEEE publication. Neither the NCRP nor the IEEE determined that there was sufficient evidence of harm. The NCRP stated that:

> *There are several thousands of reports – scientific papers, books, articles, and newspaper accounts – of widely varying scientific quality that present data or opinion on the biological response to [radio-frequency electromagnetic] radiations, no consensus has emerged regarding thresholds and mechanisms of injury at specific absorption rates (SARs) below a few watts per kilogram (W/kg).*

Nevertheless, the vast majority of new research and more recent summaries on the health effects of radio frequency radiation have focused on non-thermal effects. Other issues of interest include concerns that certain people are more sensitive to RFR than others, that certain frequency modulations are uniquely harmful, and that long-term exposure to RFR can have cumulative effects.

The IEEE (1999) stated:

> *That no reliable scientific data exist indicating that a) certain subgroups of the population are more at risk than others; b) exposure duration at ANSI C95.1-1982 levels is a significant risk; c) damage from exposure to electromagnetic fields is cumulative; or d) nonthermal effects (other than shock) or modulation-specific sequelae of exposure may be meaningfully related to human health.*

Smart Meter Measurements in Vermont

Smart meters are a part of enhancements to the electricity distribution system designed to help manage and prevent electricity demands that surpass supply throughout the day and over longer periods of time. Some smart meters relay user electricity demand information to the electricity providers using hard wire, while others use wireless devices. The wireless devices work similarly to how a mobile telephone does: a radio signal is sent from the user's meter via a small transmitter to an antenna connected to another radio transmitter, which repeats the process until the user information is collected at its final destination. This network of radio transmitter/receivers may take many shapes depending on the distribution of users and topography.

Some wireless smart meters operate at the frequency range of 902 to 928 megahertz (MHz). Other frequencies used include 2.4 gigahertz (GHz) and, to a lesser extent, 150-222, 450-470 and 950 MHz. These are frequencies also previously or currently used by mobile telephones. The radio signal from smart meter transmitters is measured in watts (W). The typical smart meter has a power level of 0.250 W or less, although some may have a power level of 1.0 W. By comparison, a mobile telephone might have a power level of 3.0 W. A cordless telephone might use 0.25 W and a wireless router used to connect computer components might use about 1.0 W.

Gatekeeper Meter Measurements

A "gatekeeper" meter is mounted on the roof of the Green Mountain Power facility in Colchester where it communicates with a nearby neighborhood where the electric meters have been replaced with smart meters. Its radio signal is more powerful than that of the smart meters as it communicates with many simultaneously. On January 11, 2012, the Vermont Department of Health obtained measurements of RFR from its antenna located at the top of the gatekeeper case.

This site is restricted from public use. The maximum permissible exposure limit for occupational exposures from this site is **3,050 $\mu W/cm^2$.**

- RFR emissions from the unit ranged from 2,100 to 2,888 microwatts per square centimeter ($\mu W/cm^2$) on contact with the transmitting antenna.

- Emissions measured 120 $\mu W/cm^2$ at 12 inches from the transmitter. RFR levels were measured at background levels at distances of three feet or more from the transmitter.

Residential Smart Meter Measurements
Also on January 11, 2012, the Health Department obtained RFR measurements from an operating smart meter on the exterior wall of a residence in Colchester, when it was instructed to download data to the gatekeeper. Measurements were taken with a Narda Model 8712 RFR Survey Meter. The surveyor has been specifically trained by Narda to obtain these readings.

This smart meter is in a residential neighborhood. The maximum permissible exposure limit for a member of the general public for RFR from this smart meter is **610 $\mu W/cm^2$.**

- Measurements of RFR during transmission ranged from 50 to 140 $\mu W/cm^2$ on contact with the smart meter in the vicinity of its transmitting antenna.

- Measurements at 12 inches from the smart meter during transmission ranged between 10 and 50 $\mu W/cm^2$. Measurements at distances of three feet or more away from the smart meter were at or near the background level.

- A separate set of measurements were made within the residence in the room on the opposite side of the wall in the photograph above. No measurements of RFR above background were recorded during multiple instructions from the gatekeeper for the smart meter to transmit.

- A separate set of measurements were made in this neighborhood for the simultaneous transmission of all smart meters. No RFR could be distinguished above background during multiple tests.

- Another smart meter at a different residence was tested to see if RFR levels would differ during a remote connection and remote disconnection of the smart meter from the network. During multiple tests of this process, RFR was measured in the range of 50 to 90 $\mu W/cm^2$ on contact with the smart meter.

- RFR was indistinguishable from background more than three feet from the smart meter during normal transmissions.

A mobile telephone was used to test the Narda RFR Survey Meter in between measurements to verify satisfactory operations. The transmission of RFR from this mobile telephone at the time of measurement was 490 $\mu W/cm^2$.

Studies of Health Effects Specific to Smart Meters

There are not yet any research studies on health effects using smart meters as the source. The devices are very similar to mobile telephones in both radio frequency and radio power. As such, looking at the health effects research where mobile telephones are the source of RFR exposure makes sense.

One important difference between exposure from smart meters and mobile telephones is that of the physical arrangements of exposure. While a mobile telephone exposes the user's eyes, skull and brain with a transmitting antenna in close proximity, smart meters are fixed sources attached to the outside of buildings. This should make comparisons to the health effects research findings from mobile telephones a "worst case scenario."

Vermont is not the first state to investigate the health impacts of smart meters. Both Maine and California have previously published their assessment of smart meters for public health impacts. The following are summaries from recent efforts to characterize health risk from smart meter RFR conducted by the Maine Center for Disease Control, the California Council on Science and Technology and the Monterey County, California Health Department.

Maine Center for Disease Control

The Maine Center for Disease Control assembled a panel of state government leaders to review the scientific literature on smart meter and mobile phone RFRs, and published a summary opinion:

> *Our review of these national and international government or government-affiliated assessments indicate a broad consensus that studies to date give no consistent or convincing evidence of a causal relation between RF exposure in the range of frequencies and power used by smart meters and adverse health effects.*
>
> *We found little information in these assessments that spoke directly about the safety of RF exposure from smart meters. There is, however, much discussion about the safety of mobile phones. Mobile phone use represents an RF exposure qualitatively similar to smart meters in range of frequency, but because the power is higher and typical use results in exposure closer to the body, the resulting exposure to RF appears to be quantitatively much greater than that from smart meters. Thus, it appears to us that the lack of any consistent and convincing evidence of a causal relation between RF exposure from mobile phones and adverse health effects would indicate even less concern for potential health effects from use of smart meters.*

The full report is available at: http://www.maine.gov/dhhs/mecdc/environmental-health/documents/smart-meters-maine-cdc-executive-summary-11-08-10.pdf

Maine CDC also published a summary of the specific documents reviewed about smart meters and RFR: http://www.maine.gov/dhhs/mecdc/environmental-health/smart-meters.shtml

California Council on Science and Technology
The California Council on Science and Technology made a comprehensive review of the costs and benefits of smart metering, including a comparison of RFR emissions from various technologies and the real and perceived risks of RFR exposure from smart meters. The full report is available at:
http://www.ccst.us/publications/2011/2011/smartA.pdf

Monterey County Health Department
Like the Maine CDC, the Monterey County Health Department published its summary of a literature review. The full report is available at:
http://publicagendas.co.monterey.ca.us/MG97205/AS97224/AS97230/AI99413/DO99416/DO_99416.pdf

Health Effect Studies from a Regulatory Perspective

In the U.S., the FCC has long used the guidance of the National Council for Radiation Protection and Measurements. Before the FCC established its role (primarily due to the evolution of wireless technologies), industry standards of the Institute of Electrical and Electronics Engineers were used to establish RFR safety in the workplace and for the general public. The FCC is part of a federal Interagency Working Group. Other members include the Food and Drug Administration, the Occupational Safety and Health Administration and the Environmental Protection Agency.

In many parts of the rest of the world, regulations are adopted from standards recommended by the World Health Organization (WHO). The WHO relies on the work of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for science-based guidance in establishing regulatory recommendations.

National Council for Radiation Protection and Measurements (NCRP)
NCRP Report Number 86, *Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields*, provides the basis of current regulations for protecting workers and the general public as adopted by the FCC. This 1986 report is a comprehensive review of the thousands of research studies conducted up to that date. The research covered most areas of physical harm possible from RFR.

The NCRP guidance resolved on preventing thermal effects from what they called radiofrequency electromagnetic (RFEM) radiations, as measured by specific absorption rates (SAR) measured in watts of energy absorbed per kilogram (W/kg) of human tissue. The research at that time led them to conclude thermal effects were the only reproducible effects, and their SAR limits of 0.4 W/kg for workers and 0.08 W/kg for the general public remain the norm today, both in the U.S. and around the world.

With regard to the growing interest in non-thermal effects, the NCRP stated:

> *Although there are several thousands of reports – scientific papers, books, articles, and newspaper accounts – of widely varying scientific quality that*

present data or opinion on the biological response to RFEM radiations, no consensus has emerged regarding thresholds and mechanisms of injury at specific absorption rates (SARs) below a few watts per kilogram (W/kg).

Institute of Electrical and Electronics Engineers (IEEE)
The IEEE has deliberated on the scientific literature of RFR exposure and effects since the 1950s. It has provided recommendations primarily to industry for protecting workers and the general public. Lacking other guidance, the IEEE standards served as the best available guidance for entities outside of industry until the NCRP published its recommendations in 1986. The IEEE health protection recommendations are similar to those of the NCRP and the International Commission for Non-Ionizing Radiation Protection (ICNIRP). The IEEE exposure limits are very similar to those adopted by the FCC and WHO.

From a 2005 publication by the IEEE's Committee on Man and Radiation:

The IEEE and other RF/microwave exposure limit standards are based principally on laboratory studies of animals using short exposure durations (hours at most). The limiting effect for whole body exposures (behavioral disruption) is clearly a thermal phenomenon. Some investigators have reported effects at much lower exposure levels, which are sometimes called "nonthermal" effects. Each version of the IEEE standard has acknowledged the existence of such reports, while at the same time indicating that they were insufficient to be considered a health hazard or to be used as a basis to develop exposure guidelines. For example, the 1991 standard states that "research on the effects of chronic exposure and speculations on the biological significance of nonthermal interactions have not yet resulted in any meaningful basis for alteration of the standard. It remains to be seen what future research may produce for consideration at the time of the next revision of this standard". Other organizations have independently reached this same conclusion.

The full publication is available at: http://ewh.ieee.org/soc/embs/comar/standardsTIS.pdf

Federal Communications Commission (FCC)
In the U.S., the FCC is the regulatory agency that has jurisdiction for health and safety relative to RFR from wireless technologies, including smart meters and mobile telephones. The FCC has promulgated limits for RFR exposure for workers and the general public. It also licenses organizations that use frequencies under its regulatory authority. Its perspective on RFR health protection is summarized in this document http://transition.fcc.gov/oet/rfsafety/rf-faqs.html#Q5:

Biological effects can result from exposure to RF energy. Biological effects that result from heating of tissue by RF energy are often referred to as "thermal" *effects. It has been known for many years that exposure to very high levels of RF radiation can be harmful due to the ability of RF energy to heat biological tissue rapidly. This is the principle by which microwave ovens cook food. Exposure to very high RF intensities can result in heating of biological tissue and an increase in body temperature. Tissue damage in humans could occur during exposure to high RF levels because of the body's inability to cope with or dissipate the excessive heat that could be generated. Two areas of the body, the eyes and the testes, are particularly vulnerable to RF heating because of the relative lack of available blood flow to dissipate the excess heat load.*

At relatively low levels of exposure to RF radiation, i.e., *levels lower than those that would produce significant heating; the evidence for production of harmful biological effects is ambiguous and unproven. Such effects, if they exist, have been referred to as "non-thermal" effects. A number of reports have appeared in the scientific literature describing the observation of a range of biological effects resulting from exposure to low-levels of RF energy. However, in most cases, further experimental research has been unable to reproduce these effects. Furthermore, since much of the research is not done on whole bodies (*in vivo*), there has been no determination that such effects constitute a human health hazard. It is generally agreed that further research is needed to determine the generality of such effects and their possible relevance, if any, to human health. In the meantime, standards-setting organizations and government agencies continue to monitor the latest experimental findings to confirm their validity and determine whether changes in safety limits are needed to protect human health.*

A more detailed report is available from the FCC Office of Engineering and Technology. OET Bulletin 56, fourth edition, published in 1999 is available at: http://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf.

Food and Drug Administration (FDA)

The FDA is a part of the Interagency Working Group, which also includes the National Institute for Occupational Safety and Health, the Environmental Protection Agency, the Federal Communications Commission, the Occupational Safety and Health Administration and the National Telecommunications and Information Administration. The FDAwill also investigate any mobile telephone that is suspected of emitting RFR in excess of FCC regulatory limits for device emissions. On its website, the FDA defines its perspective on mobile telephone RFR:

Cell phones emit low levels of radiofrequency energy (RF). Over the past 15 years, scientists have conducted hundreds of studies looking at the biological effects of the radiofrequency energy emitted by cell phones. While some researchers have reported biological changes associated with RF energy, these studies have failed to be replicated. The majority of studies published have failed to show an association between exposure to radiofrequency from a cell phone and health problems.

The low levels of RF cell phones emit while in use are in the microwave frequency range. They also emit RF at substantially reduced time intervals when in the stand-by mode. Whereas high levels of RF can produce health effects (by heating tissue), exposure to low level RF that does not produce heating effects causes no known adverse health effects.

This and other information from the FDA is available at: http://www.fda.gov/radiation-emittingproducts/radiationemittingproductsandprocedures/homebusinessandentertainment/cellphones/default.htm.

International Commission on Non-Ionizing Radiation Protection (ICNIRP)
ICNIRP is relied upon by the World Health Organization (WHO) for guidance on RFR and other non-ionizing radiation from low frequency electromagnetic fields from power lines to ultraviolet radiation. Numerous countries rely on WHO and ICNIRP guidance as they may not have the infrastructure to conduct their own science-based health protection research.

ICNIRP has updated its guidance most recently in 2009 in ICNIRP 16, *Exposure to High Frequency Electromagnetic Fields, Biological Effects and Health Consequences (100 kHz-300 GHz).* This guidance reflects consideration of a great deal of evidence available since the NCRP published its Report 86, which serves as the basis of U.S. health protection regulations. This includes 15 years of laboratory and epidemiologic study of mobile telephone use, where the primary public health concern was cancer of the head and neck. It concludes:

In the last few years the epidemiologic evidence on mobile phone use and risk of brain and other tumors of the head has grown considerably. In our opinion, overall the studies published to date do not demonstrate a raised risk within approximately ten years of use for any tumor of the brain or any other head tumor. However, some key methodological problems remain - for example, selective non-response and exposure misclassification. Despite these methodologic shortcomings and the still limited data on long latency and long-term use, the available data do not suggest a causal association between mobile phone use and fast-growing tumors such as malignant glioma in adults, at least those tumors with short induction periods. For slow-growing tumors such as meningioma and acoustic neuroma, as well as for glioma among long-term users, the absence of associations reported thus far is less conclusive because the current observation period is still too short. Currently data are completely lacking on the potential carcinogenic effect of exposures in childhood and adolescence.

Electromagnetic Hypersensitivity

The WHO provides numerous guidance documents based upon ICNIRP research and deliberation, including on electromagnetic field (EMF) hypersensitivity or EHS. See http://www.who.int/mediacentre/factsheets/fs296/en/index.html.

The WHO concluded:

> *A number of studies have been conducted where EHS individuals were exposed to EMF similar to those that they attributed to the cause of their symptoms. The aim was to elicit symptoms under controlled laboratory conditions.*
>
> *The majority of studies indicate that EHS individuals cannot detect EMF exposure any more accurately than non-EHS individuals. Well controlled and conducted double-blind studies have shown that symptoms were not correlated with EMF exposure.*
>
> *It has been suggested that symptoms experienced by some EHS individuals might arise from environmental factors unrelated to EMF. Examples may include "flicker" from fluorescent lights, glare and other visual problems with VDUs, and poor ergonomic design of computer workstations. Other factors that may play a role include poor indoor air quality or stress in the workplace or living environment.*
>
> *There are also some indications that these symptoms may be due to pre-existing psychiatric conditions as well as stress reactions as a result of worrying about EMF health effects, rather than the EMF exposure itself.*
>
> *EHS is characterized by a variety of non-specific symptoms that differ from individual to individual. The symptoms are certainly real and can vary widely in their severity. Whatever its cause, EHS can be a disabling problem for the affected individual. EHS has no clear diagnostic criteria and there is no scientific basis to link EHS symptoms to EMF exposure. Further, EHS is not a medical diagnosis, nor is it clear that it represents a single medical problem*

Earlier Research on Mobile Phones

There is only a limited amount of scientific research about the RFR from smart meters. However, the frequency of RFR from smart meters and the radiated power of transmitters employed in smart meters are the same as used in mobile telephones. This makes comparison to the scientific research on RFR from mobile telephones relevant. There is one very important difference between smart meter and mobile telephone RFR. Mobile telephone RFR is experienced by users often with the transmitting antenna very close to the body, including the skull, brain and eyes as compared to smart meters, which operate in fixed positions on the outside wall of a house or business.

The Royal Society of Canada (RSC) for Health Canada
In 1999, the Royal Society of Canada published *A Review of the Potential Health Risks of Radiofrequency Fields from Wireless Telecommunication Devices.*

This report provided a comprehensive review of the scientific literature available up to 1999 as part of Health Canada's routine activities for periodic review and revision of its safety codes. This report also concluded:

> *Scientific studies performed to date suggest that exposure to low intensity non-thermal RF fields do not impair health of humans or animals. However, the existing scientific evidence is incomplete, and inadequate to rule out the possibility that these non-thermal biological effects could lead to adverse health effects. Moreover, without an understanding of how low energy RF fields cause these biological effects, it is difficult to establish safety limits for non-thermal exposures.*

The NRPB sponsored Independent Expert Group on Mobile Phones
In 2000, the National Radiological Protection Board of the United Kingdom, now a part of the UK's Health Protection Agency, sponsored its own comprehensive review of the scientific literature, *Mobile Phones and Health.* The report may be read in full at: http://www.iegmp.org.uk/report/text.htm.

Its findings were similar to those published a year earlier by the Royal Society of Canada:

> *Despite public concern about the safety of mobile phones and base stations, rather little research specifically relevant to these emissions has been published in the peer-reviewed scientific literature. This presumably reflects the fact that it is only recently that mobile phones have been widely used by the public and as yet there has been little opportunity for any health effects to become manifest. There is, however, some peer-reviewed literature from human and animal studies, and an extensive non-peer-reviewed information base, relating to potential health effects caused by exposure to RF radiation from mobile phone technology.*
>
> *The balance of evidence to date suggests that exposures to RF radiation below NRPB and ICNIRP guidelines do not cause adverse health effects to the general population.*
>
> *There is now scientific evidence, however, which suggests that there may be biological effects occurring at exposures below these guidelines. This does not necessarily mean that these effects lead to disease or injury, but it is potentially important information and we consider the implications below.*
>
> *There are additional factors that need to be taken into account in assessing any possible health effects. Populations as a whole are not genetically homogeneous and people can vary in their susceptibility to environmental hazards. There are well-established examples in the literature of the genetic predisposition of some*

groups, which could influence sensitivity to disease. There could also be a dependence on age. We conclude therefore that it is not possible at present to say that exposure to RF radiation, even at levels below national guidelines, is totally without potential adverse health effects, and that the gaps in knowledge are sufficient to justify a precautionary approach.

In the light of the above considerations we recommend that a precautionary approach to the use of mobile phone technologies be adopted until much more detailed and scientifically robust information on any health effects becomes available.

We note that a precautionary approach, in itself, is not without cost but we consider it to be an essential approach at this early stage in our understanding of mobile phone technology and its potential to impact on biological systems and on human health.

In addition to these general considerations, there are concerns about the use of mobile phones in vehicles. Their use may offer significant advantages – for example, following accidents when they allow emergency assistance to be rapidly summoned. Nevertheless, the use of mobile phones whilst driving is a major issue of concern and experimental evidence demonstrates that it has a detrimental effect on drivers' responsiveness. Epidemiological evidence indicates that this effect translates into a substantially increased risk of an accident. Perhaps surprisingly, current evidence suggests that the negative effects of phone use while driving are similar whether the phone is hand-held or hands-free. Overall we conclude that the detrimental effects of hands-free operation are sufficiently large that drivers should be dissuaded from using either hand-held or hands-free phones whilst on the move.

Recent Scientific Findings: The Interphone Study

Much of the RFR health-related guidance of the 1990s concluded there was need for more research, especially for long-term users of mobile phones. The May 2010 publication of the results of the largest epidemiological study to date, the Interphone Study, provided it. Soon after the results were published in *Lancet*, the British medical journal, the International Agency for Research on Cancer (IARC) classified RFR from mobile telephones as a possible (Group 2B) carcinogen. This classification of RFR from mobile telephones as a possible carcinogen by IARC is explained in the press release issued at publication of the study:

Dr Christopher Wild, Director of IARC said: "An increased risk of brain cancer is not established from the data from Interphone. However, observations at the highest level of cumulative call time and the changing patterns of mobile phone use since the period studied by Interphone, particularly in young people, mean that further investigation of mobile phone use and brain cancer risk is merited.

The WHO, which includes IARC, provided more detail as to why RFR was classified as a Group 2B carcinogen:

> *The international pooled analysis of data gathered from 13 participating countries found no increased risk of glioma or meningioma with mobile phone use of more than 10 years. There are some indications of an increased risk of glioma for those who reported the highest 10% of cumulative hours of cell phone use, although there was no consistent trend of increasing risk with greater duration of use. The researchers concluded that biases and errors limit the strength of these conclusions and prevent a causal interpretation. Based largely on these data, IARC has classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B), a category used when a causal association is considered credible, but when chance, bias or confounding cannot be ruled out with reasonable confidence.*

Numerous other organizations have reflected on the Interphone Study. ICNIRP provided a comprehensive review of a study titled *Mobile Phones, Brain Tumours and the Interphone Study: Where Are We Now?* published in the journal *Environmental Health Perspectives*. The objective of the study was to review the evidence on whether mobile phone use raises risk of the main types of brain tumour, glioma and meningioma, with a particular focus on the 13-country Interphone Study. It concluded that, although there remains some uncertainty, the trend in the accumulating evidence is increasingly against the hypothesis that mobile phone use can cause brain tumors in adults.

The full report is available at: http://www.icnirp.org/documents/SCIreview2011.pdf.

Food and Drug Administration
The FDA is part of the U.S. Interagency Working Group for mobile telephone safety, and will investigate reports of excessive RFR from mobile telephones. FDA responded to the Interphone Study:

> *The study reported little or no risk of brain tumors for most long-term users of cell phones. "There are still questions on the effect of long-term exposure to radio frequency energy that are not fully answered by Interphone," says Abiy Desta, network leader for science at FDA's Center for Devices and Radiological Health. "However, this study provides information that will be of great value in assessing the safety of cell phone use."*

The full response is available at:
http://www.fda.gov/downloads/ForConsumers/ConsumerUpdates/UCM212306.pdf

This FDA consumer update cites a National Cancer Institute study that found no evidence of causality in an analysis of brain cancer incidence rates over the years 1992 to 2006, a period of rapidly growing mobile telephone use. NCI's fact sheet on cell telephones expresses its own perspective on the most recent mobile telephone epidemiological studies at http://www.cancer.gov/cancertopics/factsheet/Risk/cellphones:

Studies thus far have not shown a consistent link between cell phone use and cancers of the brain, nerves, or other tissues of the head or neck. More research is needed because cell phone technology and how people use cell phones have been changing rapidly.

The Health Physics Society (HPS)
The HPS is a professional organization of radiation protection professionals. HPS publishes fact sheets for public outreach, and one on mobile telephone RFR starts with:

To date, no adverse health effects have been established for mobile phone use. However, epidemiology data regarding long-term (more than 10 years) use of mobile phones (also known as "wireless" or "cell" phones) are sparse and unreliable and do not permit conclusions to be drawn about possible risks from long-term use of mobile phones.

The fact sheet provides also includes other recent expert assessments, such as from the European Commission Scientific Committee on Emerging and Newly Identified Health Risks, which stated in 2007:

No health effect has been consistently demonstrated at exposure levels below the ICNIRP limits established in 1998. The data for this evaluation is limited, especially for long-term, low-level exposure.

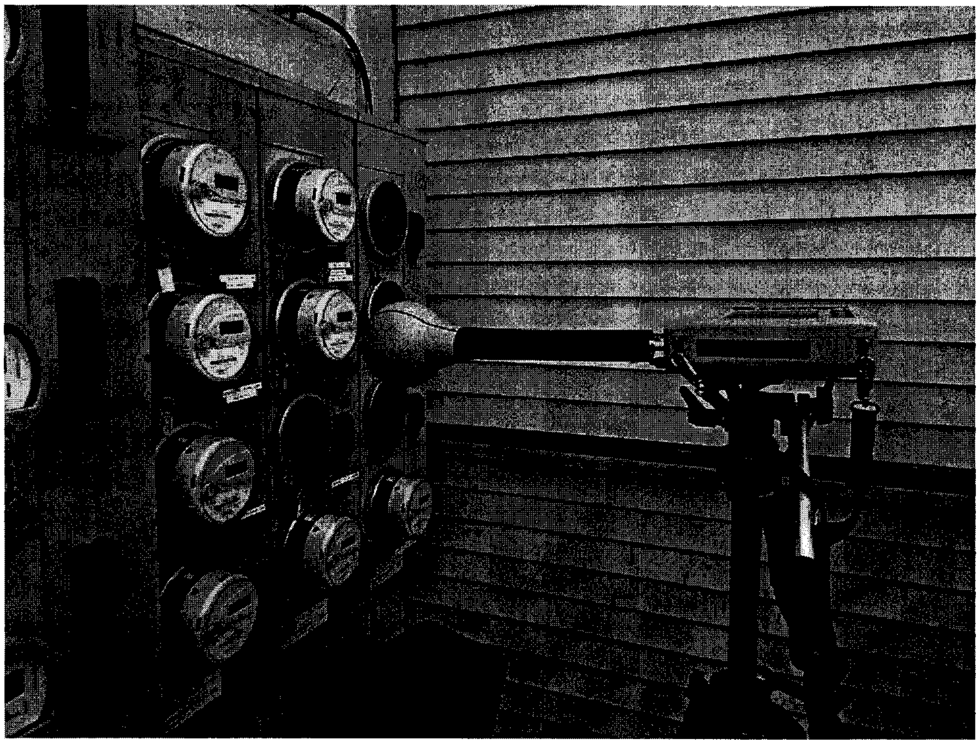
It also cites the Swedish Radiation Protection Authority for its 2008 opinion:

Short-term use of mobile phones does not appear to be associated with brain or head and neck cancer risks in adults." It also cites ICNIRP 16, Exposure to High Frequency Electromagnetic Fields, Biological Effects and Health Consequences (100 kHz-300 GHz) where the Commission stated "results of epidemiological studies to date give no consistent or convincing evidence of a causal relation between RF exposure and any adverse health effect.

The full fact sheet may is available at:
http://hps.org/documents/Mobile_Telephone_Fact_Sheet_update_May_2010.pdf

RICHARD TELL ASSOCIATES, INC.

An Evaluation of Radio Frequency Fields Produced by Smart Meters Deployed in Vermont



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An Evaluation of Radio Frequency Fields Produced by Smart Meters Deployed in the State of Vermont

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An Evaluation of Radio Frequency Fields Produced by Smart Meters Deployed in the State of Vermont

Summary

During November and December, 2012, a comprehensive series of measurements was performed for the Vermont Department of Public Service to evaluate radiofrequency (RF) emissions produced by electric smart meters deployed within the state. A primary impetus for the study is the current public concern about smart meter generated RF fields (the signals produced by the meters) and the potential for such fields to cause adverse biological effects. This study was aimed at assessing compliance of smart meter signal intensities with regulations established by the Federal Communications Commission (FCC) that prescribe limits for safe exposure of humans.

As commonly implemented in many parts of the country, the smart meter systems investigated in Vermont are configured as mesh networks wherein each end point meter installed on a home can wirelessly communicate with other neighboring meters as well as data collection points referred to as Gatekeepers by Green Mountain Power (GMP) and Cell Routers by Burlington Electric Department (BED). Each data collection point can serve some hundreds of end point meters and send the electric energy consumption data received from the meters back to the electric utility company via a wireless wide area network (WWAN) or over a fiber optic network.

The study included extensive measurements of smart meter RF fields in one of the GMP service territories in the Rutland, VT area and in the BED service territory within Burlington, VT. In total, measurements were conducted at 37 different locations in the state which included 18 residential sites, six banks of smart meters (four of which were on residences), two data collection points (one each in the GMP and BED areas), one isolated meter and 14 general environmental measurement sites. Field measurements were accomplished with a spectrum analyzer based selective radiation meter (Narda model SRM-3006) permitting direct measurement of the intensity of RF fields expressed as a percentage of the FCC maximum permissible exposure (MPE) values. The instrumentation also allowed for time analysis of the detected RF fields from which the duty cycle of the RF emissions could be determined.

The meters deployed by both GMP (manufactured by Elster) and BED (manufactured by Itron) operate as RF local area networks (RF LANs) in the configuration of a mesh network and communicate within the FCC designated license free band of 902-928 MHz. The internal radio transceivers operate at low powers of 182 milliwatts (mW) and 304 mW by GMP and BED respectively.

Summary

- Consistent with certification reports filed with the FCC on behalf of smart meter manufacturers by independent test labs, the instantaneous peak values of RF fields found in this study, without any consideration of time or spatial averaging, comply with the MPE.

- Smart meters produce intermittent bursts of pulsed RF fields that are small when compared to the FCC MPE for public exposure[1]. When the field is adjusted for duty cycle and spatial averaging, in accord with FCC rules, the resulting maximum value of potential exposure at one foot directly in front of the meter represents about 0.068% of the time-averaged/spatial-averaged exposure limit for GMP meters and 0.032% in the case of BED meters.

- The smart meter emissions decrease sharply with increasing distance from the meter being equivalent to about 0.0013% of the exposure limit (time averaged and spatial averaged) at 10 feet from the meter (equivalent to 3,800,000 times less than the actual hazard threshold).

- Maximum duty cycles were in the 3–4% range and were comparable to duty cycles found in earlier studies [1, 2].

- Exposure, in terms of instantaneous peak as well as time-averaged RF fields, caused by deployed smart meters in Vermont is small in comparison to that related to many other sources of RF fields in the environment. For instance, local values of long term, time-averaged RF fields (as a fraction of the MPE) from FM radio broadcasting can, in some areas as found in this study, be as much as ten to hundreds of times greater than those values found immediately near smart meters. The common use of normal appliances within a home or office, such as microwave ovens and wireless routers, can lead to RF fields that are comparable to or substantially greater than those produced by smart meters. This applies to the use of mobile phones as well; both mobile phones and smart meters operate with roughly the same transmitter peak powers. In this context, however, mobile phones are normally held against the head during use while smart meters are not.

- Low frequency electric and magnetic fields produced by the smart meters and their internal switch mode power supplies, at one foot from the meters, were substantially smaller in value than recommended limits [13].

[1] For convenience in this report, the term pulse is used interchangeably with the term burst.

Summary

- Smart meters make use of pulsed RF signals, a characteristic common to other devices found in the everyday environment such as wireless routers, radar systems used for air traffic control and most mobile phones.

- Peak RF fields associated with large banks of smart meters are not materially different from those of a single meter. Average RF field levels can be greater due to the number of meters. However, there is no general correlation between overall higher average RF fields associated with large banks of meters since the greatest duty cycle of any given smart meter appears to be more related to a specific meter's position within the wireless network's hierarchy, i.e., how close it is, from a communications perspective, to its data collection point. Hence, a single meter that serves to relay energy consumption data from many other meters to the data collection point can exhibit a greater time-averaged RF field than a large group of meters that are not close, network wise, to a data collection point.

- Of 141 interior RF field measurements inside residences, the greatest measured value was equivalent to 0.0014% of the MPE in term of time-averaged and spatially-averaged exposure. This maximum value was associated with a location directly behind the installed smart meter but inside the home. The average interior residential RF field, time and spatially averaged, was equivalent to 0.000058% of the MPE.

The FCC MPE values were derived with the inclusion of a safety factor of 50 below the actual threshold of hazard from prolonged exposure. When the above estimated RF field exposures for GMP and BED meters at the closest distance of one foot are considered in this light, this means that the most conservative estimates of potential exposure range between approximately 75,000 and 156,000 times less than the hazard threshold respectively.

Using the highest indicated results from the measurements performed in this study, potential exposure of individuals to the RF fields associated with the currently deployed smart meters in the GMP and BED service territories is small when compared to the limits set by the FCC. It is concluded that any potential exposure to the investigated smart meters will comply with the FCC exposure rules by a wide margin.

Introduction

The work documented in this report is related to an evaluation of the radiofrequency (RF) emissions associated with the operation of electric smart meters in Vermont. A proliferation of smart meters across the nation, as a component of the so-called smart grid initiative in the United States, has raised the question among some in the public of how the RF emissions of these new technology meters compare with limits that have been set for safe human exposures. Recent studies have determined that the low power of the radio transceivers inside the meters results in only low level RF fields that comply with Federal standards, generally by wide margins [1, 2, 3]. Nonetheless, this relatively new technology that includes the production of brief but numerous pulses of RF energy and the sheer number of emitters (one on each home and business) continues to elicit questions regarding smart meter emissions and has influenced a more in-depth examination of smart meters in Vermont. This study, commissioned by the Vermont Department of Public Service, explored the RF emission characteristics associated with smart meters being deployed by two electric utilities in Vermont, Green Mountain Power (GMP) and the Burlington Electric Department (BED). These two utilities employ smart meters that were presumed to be representative of most smart meters within the state (GMP makes use of meters manufactured by Elster and BED uses meters by Itron). At the time of the study, GMP had deployed approximately 95,000 smart meters of a future total estimated number of 180,000 meters in its service territory. BED had deployed approximately 14,000 meters within its relatively small service territory within the city of Burlington extending some six miles north and south and three miles east and west. The field work in Vermont occurred during November and December, 2012.

Electric power meters are designed to measure the amount of electric energy used by a customer and are calibrated to read in terms of the unit kilowatt-hour (kWh).[2] Older style electro-mechanical power meters, with rotating disks, were first widely introduced by Westinghouse and have been used for over 100 years [3]. Such meters are referred to as analog meters and have proved to be extremely reliable. Usually, monthly, a utility meter reader visits the site of the meter to manually record how much energy has been consumed during the previous month. However, with the introduction of digital electronics in electric power meters, and RF technology more recently (approximately 2006), the smart meter communicates energy consumption data wirelessly to the electric utility company. Wireless smart meters are generally referred to as a part of advanced metering infrastructure (AMI).

This study examined the strengths of the RF fields emitted by smart meters with attention to both the instantaneous peak values of field power density and average values. The work also included measurements of the duration of the brief emissions and

[2] A kilowatt-hour (kWh) represents an amount of energy used by an electric load of one kilowatt of electric power over a period of one hour.

the number of emissions that could be observed to occur over sampling intervals so that the amount of time that the meters actually transmit could be determined[3]. Effort was made to identify the maximum amount of transmitter activity that might occur during smart meter operation.

A primary focus of the measurements was, ultimately, to develop data to allow for an accurate and precise comparison of smart meter emissions in Vermont with the regulatory exposure limits promulgated by the Federal Communications Commission (FCC) [4], as well as to other common RF emission sources.

[3] This is related to a term called duty cycle, described later in this report.

Smart Meter Mesh Networks

To better understand the challenge of characterizing RF fields of smart meters, it is helpful to envision how the meters work and how they are configured in a geographic area to report energy consumption data. Both of the meter types used by GMP and BED are deployed as so-called mesh networks. The term "mesh" refers to the geographic distribution of smart meters throughout a neighborhood area wherein each meter has the ability to communicate with other neighboring meters and each meter can be called a node in the network. When the many nodes of the network are viewed on a diagram, it resembles the rough geometrical shape of a mesh.

Associated with operation of the mesh network is the requirement that the data that each meter generates, somehow, gets back to the electric utility company. This can be accomplished via alternative means including land line telephone, fiber optic network coverage or a wireless link, typically through use of a wireless data plan with a cellular carrier that serves the area with a Wireless Wide Area Network (WWAN). So, each end point meter (the meter attached to a home) would ideally be able to communicate directly to the data collection point from where the data would then be uplinked via a wireless Internet connection (as used by GMP) back to the utility or placed on an area fiber optic network (as used by BED). However, this ideal link between each end point meter and the data collection point is rarely achieved in a single "hop" except for meters that happen to be located close to the collection point and, rather, the data from each meter is relayed to the data collection point via the data signals hopping between various smart meters such that the data eventually arrives at the collection point. Each end point meter identifies a suitable communications route by briefly communicating with other meters from time to time, storing this path information in its memory and, then, when sending its data, using the routing information it has retained to communicate to the data collection point via some number of "hops"[4]. Mesh networks are complex in that if, for some reason, a communication path is blocked, the network can identify an alternative routing, ultimately, to get the data to the collection point. This aspect of mesh networks is sometimes referred to as the network being "self healing"; i.e., it has the ability to dynamically adjust to conditions for reliable communication by invoking the use of different end point meters in the region for communications assistance. Larger geographic areas are typically broken into different networks where each network may consist of about 400 to 500 end point meters each. Figure 1 illustrates a simple smart meter mesh network topology (physical configuration).

The electric utility company receives "load profile" data for each end point meter from the data collection points several times each day. In the case of GMP, data is

[4] In this context, a hop refers to a transmission between two end point meters.

received every six hours or four times per day. For BED, load profile data is obtained every eight hours or three times per day. The load profile data consists of 15-minute

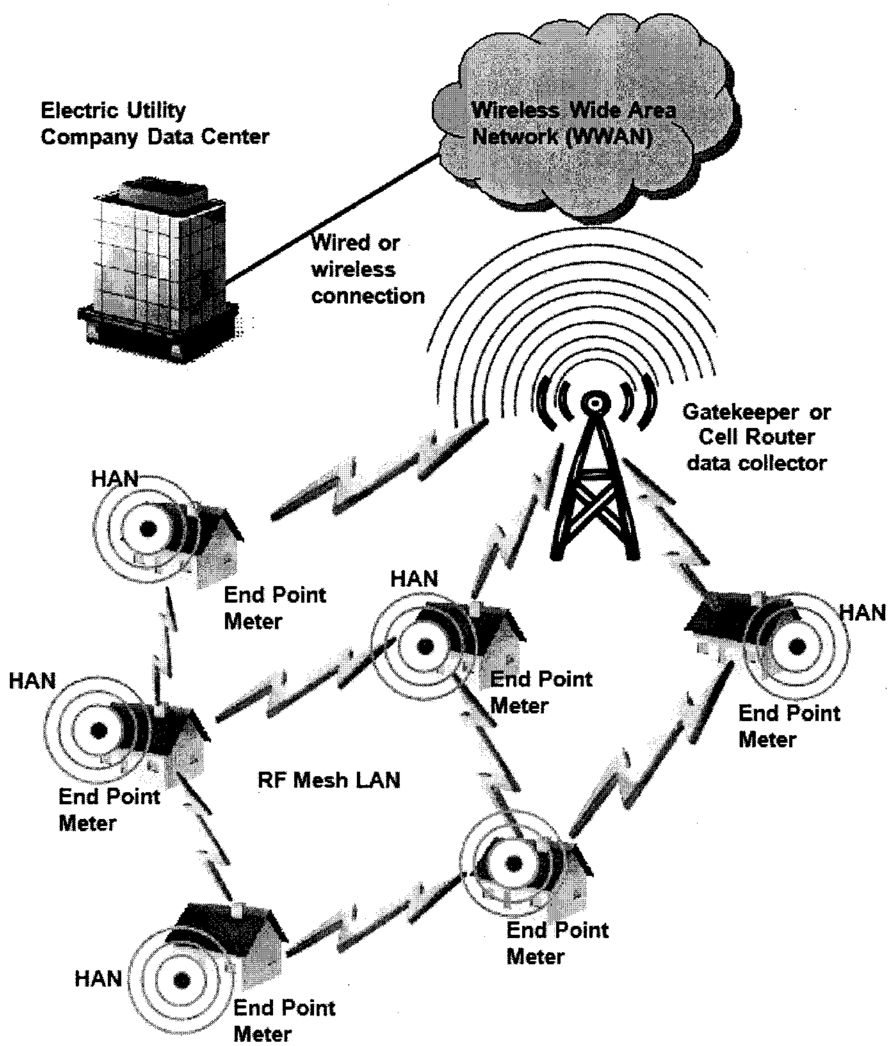

Figure 1. Simplified diagram of a smart meter mesh network configuration. Some meters communicate directly with the data collector while the signal from some meters must hop from meter to meter to reach the tower-mounted data collector. Data is sent to the electric utility company, in this example, from the data collector via a WWAN connection to the Internet. The RF LAN for the two smart meter systems studied operates in the 902-928 MHz license free band. HANs are illustrated if such capability is implemented in the future.

interval reads from the meter. The interval reads may consist of energy consumption, voltage levels and other electrical parameters. The total amount of time that smart meters actually emit RF fields over the period of a day, however, is extremely small with transmission of signals increasing when each meter receives a request to report past interval data. However, smart meters are not totally "silent" during other times; meter

RF activity typically occurs throughout the day with periodic signals used to maintain its organization within the network and to assist other meters in relaying data upstream toward the data collection point. Hence, although the meter transmissions consist of only very brief signals, lasting typically only fractions of a second in duration, it is common to observe these intermittent emissions all during the day with the amount of activity varying according to what the meter is doing at the time. At locations where a bank of meters exists, it is normal to observe more transmitter activity due to the cumulative number of meters.

Different smart meter manufacturers call the data collection points by different names but they serve the same basic purpose. In the case of Elster meters, the term "Gatekeeper" is used while for the Itron meters, the term "Cell Router" is used[5]. A difference between the GMP networks and the BED networks is that GMP makes use of a digital cellular link (WWAN) for transmitting data from all of the meters served by the Gatekeeper back to the company. In the case of BED, the company takes the data collected by its Cell Routers and places it on a fiber optic network that exists throughout the city of Burlington for transmission back to the company (in this case, there are no RF emissions associated with this delivery of data from the Cell Router to the company). In each case, either the Gatekeeper or Cell Router queries each end point meter via the RF LAN 900 MHz radio, receives the data from the end point meters associated with the particular Gatekeeper or Cell Router, stores these data and then communicates the aggregate data back to the utility either four or three times throughout the day. At the time of the study, GMP employed some 267 Gatekeepers (out of a future potential number of some 500) while BED made use of 27 Cell Routers as data collection points. Both GMP and BED used elevated locations for the Gatekeeper or Cell Router, typically on telephone or power poles within the region served by the device.

Both the Elster and Itron meters use low power radio transceivers inside the meters for the meter-to-meter communications within the mesh networks, referred to as an RF LAN (RF local area network), that operate in a license free band designated by the FCC in the 902 MHz to 928 MHz frequency range (the terminology of the 900 MHz band and 900 MHz radios will be used commonly throughout this report in the interest of brevity). Each Gatekeeper or Cell Router also contains a similar 900 MHz radio transceiver for the communication between it and various end point meters. In the case of the Gatekeeper, a WWAN transceiver (very similar to an AirCard that might be used with a laptop computer for connection to a high speed digital network)[6] is the device responsible for connection to the WWAN. This WWAN transceiver module (also commonly called a modem) is similar to a cell phone and operates with approximately

[5] Itron uses the name Cell Router since the device has the ability to transmit via a WWAN but in the case of the Cell Routers used by BED, the transmission is via a fiber optic link installed by the city.

[6] Note that a WWAN is different from common WiFi which allows wireless connectivity between computers and so-called hot spots and wireless routers typically used within homes for distribution of the Internet.

the same power as a cell phone. Depending on the particular wireless carrier that provides the WWAN service to the utility company, the operating frequency of the WWAN transceiver may be in several different bands but typically either the 800-900 MHz or 1.9 GHz bands.

A common and additional feature of smart meters is the provision of the means for implementing a Home Area Network (HAN). A HAN provides for a separate wireless connection between the meter and devices inside the home such as an "in home display" (IHD) for displaying electric energy consumption from moment to moment. This communication feature is accomplished with a lower power radio transceiver that normally operates in the license free band of 2.4 to 2. 5 GHz (referred to as the 2.4 GHz band in this report). The HAN radio, as it is referred to, makes use of a low data rate digital communications protocol with the name ZigBee and often, this radio is simply called a ZigBee radio. Not all smart meters are equipped with a HAN radio but it is a rather common practice to do so. Both the Elster and Itron meters deployed by GMP and BED, respectively, contain HAN radios. However, at the time of this study, neither GMP nor BED had implemented the HAN radios for day-to-day use by customers. Only in the case of some homes in the Rutland area, in the GMP service territory, have the HAN radios been "commissioned" to communicate with an IHD on an experimental basis to test the ability of the HAN to operate properly. Richard Tell Associates discovered during the course of the study that, contrary to what GMP had originally told the Department of Public Service, all the HAN radios within the GMP smart meters were observed to emit short, infrequent RF pulses[7]. The BED had not activated the use of the HAN radio at any end point meter.

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[7] After learning that HAN or Zigbee radios in GMP and Stowe Electric Department smart meters are actively emitting RF pulses, the DPS sent a letter to the utilities on December 11, 2012, and GMP and Stowe responded on January 2, 2013 to say that meter manufacturer Elster is working on a firmware update to be released by the end of June 2013 that would shut off the HAN radio emissions until such time that the devices are ready to be commissioned to pair with IHDs.

Basic Meter Specifications

Basic Meter Specifications

This study examined RF fields associated with two different meter types manufactured by Elster and Itron (Figure 2). Both meters are of the 200 ampere class rated for residential service and contain both 900 MHz and 2.4 GHz radios.

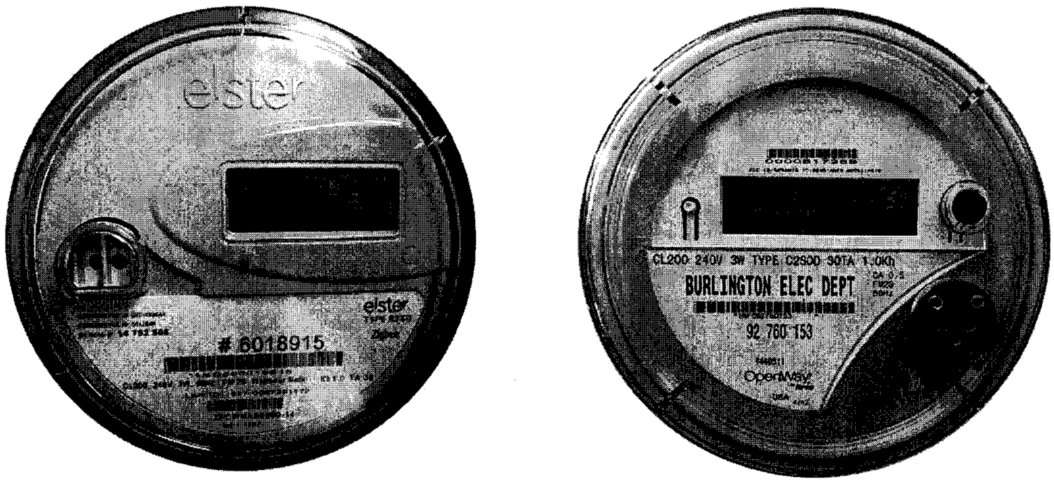

Figure 2. The Elster (left) and Itron smart meters deployed within the state of Vermont by Green Mountain Power (GMP) and the Burlington Electric Department (BED).

Prior to sale of these meters, the manufacturers must submit the meters to a series of laboratory tests to insure that they meet technical requirements of the FCC[8] such as compliance with transmitter output power, harmonic production, etc. such that they may be used within the FCC's license free bands. Once entered into the FCC's database of equipment authorizations, an FCC identification number is assigned to each device for which testing has been accomplished.[9] The relevant reports provided to the FCC for the Elster and Itron meters to support the finding of compliance with FCC rules on human RF exposure are reproduced in Appendices A and B respectively. Table 1 summarizes the relevant technical specifications of each meter in terms relevant to assessing RF fields.

[8] This process is designated as a part of the FCC's equipment authorization process.
[9] The FCC equipment database is found at: http://transition.fcc.gov/oet/ea/fccid/

Basic Meter Specifications

Table 1. RF specifications of the Elster and Itron smart meters being used in Vermont that are relevant to consideration of RF fields that may be produced by them.				
	Elster		Itron	
	FCC ID Numbers			
Specification	QZC-RX2EA4/G8JZGB1		SK9AMI6	
Band of operation	RF LAN (900 MHz)	HAN (2.4 GHz)	RF LAN (900 MHz)	HAN (2.4 GHz)
Transmitter power output-dBm (mW)	22.6 dBm (182)	18.7 dBm (74.8)	24.8 dBm (304)	18.9 dBm (78.3)
Antenna gain (dBi)	5.64	0	2.2	3.8
Maximum EIRP- dBm (mW)	28.2 (667)	18.7 (74.8)	27.0 (505)	22.7 (188)
Frequency range (MHz)	902-928	2400-2500	902-928	2400-2500

The 900 MHz RF LAN transceivers in the smart meters use a frequency hopping spread spectrum digital modulation scheme wherein the emitted RF signal hops randomly over a series of frequencies across the band. In the Elster meter, the transceiver hops over 25 different, specific frequency channels within the 902-915 MHz part of the band while the Itron meter uses 52 hopping frequency channels distributed across the entire 902-928 MHz band.

The HAN radios employ direct sequence spread spectrum modulation on 16 possible channels across the 2.4 to 2.5 GHz (2,400 MHz to 2,500 MHz) band. It is relevant to note that the 2.4 GHz band is also widely used for other applications including, most notably, operation of microwave ovens, cordless telephones and wireless routers used for distribution of Internet content.

The data collection points, represented by Gatekeepers (GMP) and Cell Routers (BED), are composed of 900 MHz radios that are essentially the same as those found in end point meters for connectivity with the RF LAN and with the end point meters that they serve. For the WWAN connection, for sending data back via the Internet to the electric utility, a cellular modem designed to operate on one of the WWAN frequencies is employed that has nominally the same power characteristics of a mobile (cell) phone. Also, since the Gatekeepers and Cell Routers used by GMP and BED are mounted high above ground, common public access to the immediate region of the units is eliminated.

The in home display (IHD) used during measurements for evaluating the HAN radio characteristics was the Tendril model IHD-5 that carries the FCC ID of TFB-APEXLT. This unit has a manufacturer's specified output power of 20 dBm (100 mW) but during laboratory testing for its certification was found to produce only 18.56 dBm (72 mW). The IHD contains an internal "inverted F" type of antenna on the unit's printed circuit card.

Assessing Potential Exposure to Smart Meter RF Fields

Smart meters present a considerable challenge to the assessment of potential exposure that can occur in their vicinity. Issues include the fact that the transceivers in the meters are low power, less than one watt, the RF fields are not uniform around the meter due to directional properties of the internal antenna and the effects of the meter box in which the meter is installed and the typical emissions of smart meters consist of very brief bursts of pulses of RF energy lasting normally less than one-tenth of a second or far less. Additionally, the amount of transmitting activity of a smart meter typically varies throughout the day and depends not only on its normal transmission of data at prescribed times during the day but, also, on whether it is assisting other meters in relaying data to other meters. Further, current human exposure limits are specified in terms of time-averaged levels of RF fields and in terms of spatial averages over the body dimensions [5]. Finally, for frequency hopping systems, such as those employed by the meters deployed by both GMP and BED, the frequency of the emission can rapidly change. Characterizing the RF emissions is, therefore, not always straightforward.

Several factors determine the magnitude of RF fields that can be produced by any source at a given point. These include the effective isotropic radiated power (EIRP) in the relevant direction, the mounting location of the source relative to where an individual may be and the duty cycle of the source (i.e., a measure related to the amount of time that the transmitter actually transmits a signal). For evaluating compliance with RF exposure standards, the time-averaged value of plane wave equivalent power density is usually the most fundamental aspect of specifying exposure. Existing RF exposure standards specify averaging times of either six minutes, normally applied to assessing occupational exposures, or 30 minutes, usually applied to exposure assessment for members of the general public.

The antennas contained within smart meters are not omnidirectional, although the pattern of emitted field is commonly very broad and can approximate the pattern of an omnidirectional source; there is, however, usually a preferred direction in which the strongest RF field is transmitted, normally away from the front of the meter with directions of reduced RF fields usually to the sides and almost always toward the rear of the meter. When a wireless smart meter is installed in a meter socket (typically in the electric service panel on a home), the metal electrical box that contains the meter socket interacts with the RF fields to distort what the antenna pattern would be in the absence of the meter box. The meter box can also provide significant shielding in directions to the rear of the meter, generally in directions toward the home on which the meter is installed, such that interior RF field strengths (or power densities) inside the home will be significantly less than at equivalent distances but in front of the meter.

The signal pattern of the smart meter antenna determines the intensity of the transmitted RF field in both the azimuth (horizontal) plane and elevation (vertical) plane. The significance of this is that the RF fields found near smart meters can be relatively non-uniform due to the metal components of the meter itself and the metal box within which it is mounted. This results in exposure of the body that can be highly non-uniform. Since exposure limits are based on spatial averages over the body as well as time averages over time, compliance assessments normally include a measure of the spatial variation of field along the vertical axis of a person standing near the meter. This means that the body-averaged value of exposure will be less than the spatial peak value that might occur directly in front of the meter where the field is most intense. Nonetheless, for purposes of this study, measurements of RF fields at the height of the meter were obtained for exterior locations near the meter. Limited data were also obtained to document the variation in field over a distance from ground level to six feet (1.83 m) above ground so that spatial average values of field could be estimated from the measured spatial peak values of fields.

Because the transmitted fields from smart meters can exhibit a dependency on direction away from the meter, mounting locations will strongly influence the exposure values for a person near the meter. If the meter is mounted relatively high above ground, most of the body may be exposed to only very weak RF fields. If the meter is mounted lower, more of the body may be subjected to stronger emissions since the body may intercept most of the transmitted fields within the elevation plane. The issue of how much more localized exposure of the body is when compared with the average over the entire body dimension depends strongly on the distance between the meter and a person; the greater the distance from the meter, the more uniform the field across the body will be but, at the same time, the weaker the field will also be, simply because of the typical rapid decrease in RF field with distance.

The RF exposure limits adopted by the FCC are based on averages over time [5]. For the smart meters used by GMP and BED, this is determined by the duty cycle of emissions and, as discussed above, exposure will depend on occupancy of areas near the meter. Closer distances can result in greater exposure while farther distances result in lower exposure. The issue of averaging of RF field power density, based on the duty cycle of emissions, with specific reference to smart meter emissions has been addressed by the FCC [6]. The FCC states that the "source based" time-averaged value of power density is the relevant factor with respect to compliance with their exposure rules. In summary, estimates of potential exposure to the GMP and BED smart meters were accomplished by determining both the instantaneous peak and average values of RF field power density near the smart meters directly in front of the meters as well as inside homes equipped with smart meters.

In total, smart meter measurements were performed at 23 sites in the GMP Rutland (13 sites) and BED (10 sites) service territories. These sites included measurements at 18 residences (12 detached homes and six apartments) as well as six meter banks (four meter banks were on apartment buildings included as residences), two data collection points (one GMP Gatekeeper and one BED Cell Router) and a single, isolated smart meter mounted on a pole in Rutland. Measurement locations for the Rutland and Burlington areas are illustrated on maps shown in Figures 3 and 4 respectively.

Because present day RF exposure limits are based on time-averaged values of RF power densities, considerable effort was applied to collecting data on smart meter duty cycles at many of the measurement locations (see section below on technical approach used in this project).

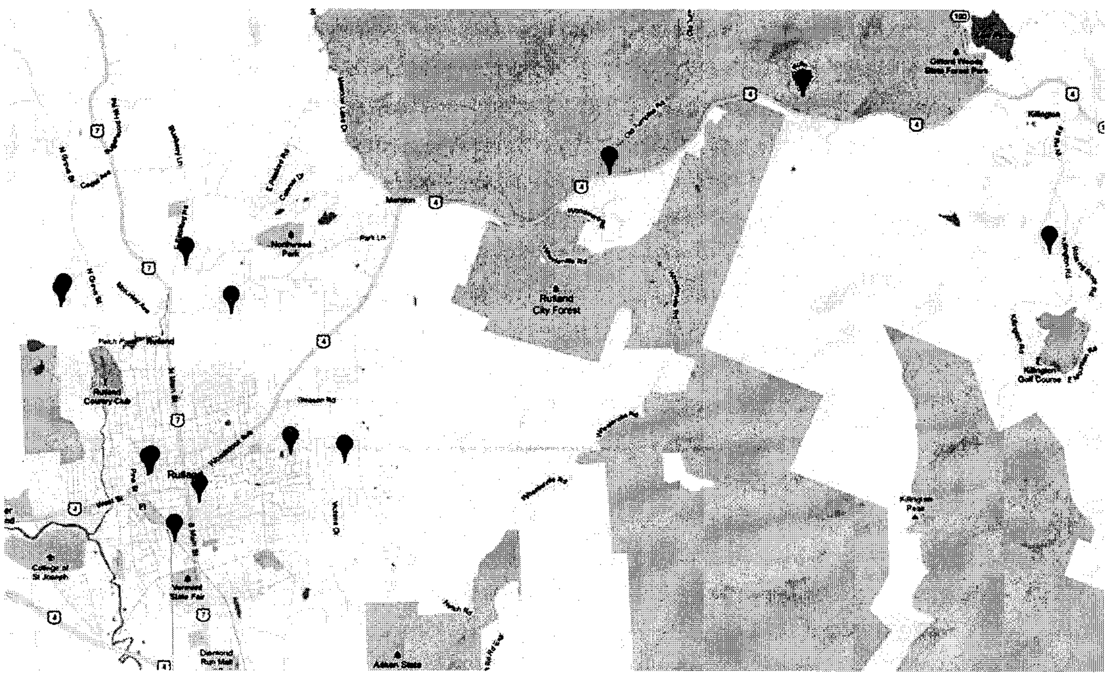

Figure 3. Smart meter measurement locations (13 total) in the Rutland, VT GMP service territory. Sites 9 and 10 and 12 and 13 are close together.

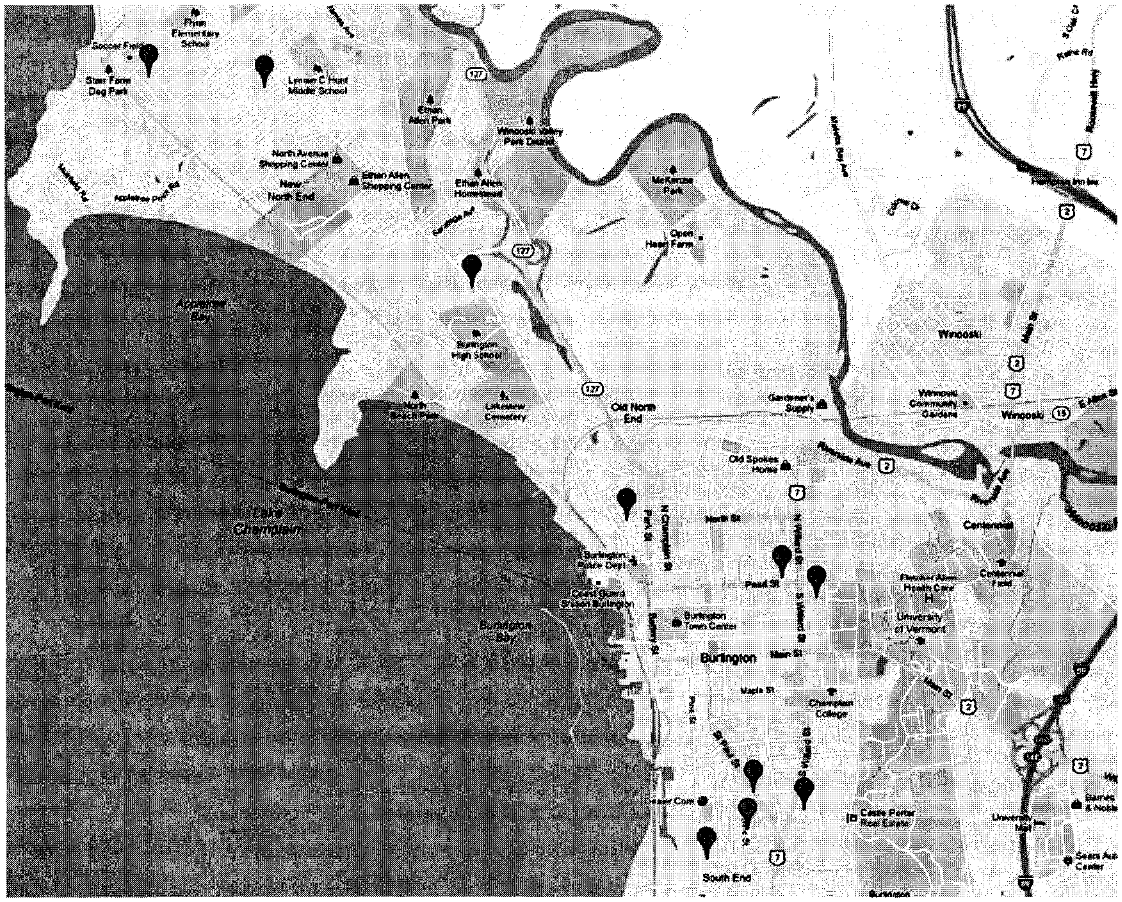

Figure 4. Smart meter measurement locations (10 total) in Burlington, VT in the BED service territory.

RF Exposure Limits

RF Exposure Limits

Recommended safe exposure limits in the United States have existed since the 1960's. Over the years, these limits have evolved to account for more recent research findings relative to biological effects of RF fields. Internationally, the three most prominent exposure limits include those of the FCC [4] and the Institute of Electrical and Electronic Engineers (IEEE) [7] in the U.S. and the guidelines of the International Commission on Non-ionizing Radiation Protection (ICNIRP) in Europe [8].

In the United States, the controlling limits for human exposure are those adopted by the FCC[10]. FCC maximum permissible exposures (MPEs) apply to FCC licensees but also apply to the use of RF emitting equipment used in the license-free bands. Because of this, smart meters are evaluated prior to sale to utility companies for compliance with the FCC's RF exposure limits and such evaluations are documented in equipment certification reports provided by the manufacturer to the FCC (see above discussion of where these reports can be found). Table 2 summarizes the MPEs from the FCC that are applicable to the emission frequencies associated with the smart meters evaluated as part of this project[11].

Table 2. FCC MPEs applicable to the RF fields produced by smart meters operated by GMP and BED in the state of Vermont. MPE values are in terms of power densities averaged over 6 minutes for occupational exposure and 30 minutes for exposure of the general public. The limits given are in terms of spatially-averaged values of power density averaged over the dimensions of the body and averages over 6 minutes or 30 minutes as the case may be.

Frequency	902-928 MHz		2.4-2.5 GHz	
	General public	Occupational	General public	Occupational
MPE (mW/cm^2)	0.601-0.619	3.00-3.10	1.0	5.0

It is relevant to note that compliance with the FCC MPEs for general public exposures allows for time averaging so long as the modulation of the field is source based, i.e., inherently a consequence of the way the source operates. Examples include the pulsed RF fields produced by radars, the typically intermittent operation of two-way mobile and portable radios and, in this case, the normal intermittency of smart meter emissions [6]. For situations in which the continuous RF field exceeds the MPE, however, the FCC has taken the position that time averaging is not permissible for showing compliance with the exposure rules in the case of public exposure. This is based on the

[10] The FCC MPEs are somewhat greater in value than the ICNIRP guidelines in the 900 MHz band. For example, at 915 MHz, the ICNIRP reference level is 0.457 mW/cm^2 vs. 0.610 mW/cm^2 used by the FCC.

[11] The MPE is a value of exposure in terms of a time-averaged value that is 50 times less than the threshold for potentially adverse biological effects (i.e., the MPE contains a safety factor of 50) for general public exposure and 10 times less for occupational exposure (i.e., the MPE contains a safety factor of 10).

conservative assumption that compliance would only be achievable if an individual physically moved about to result in a variable exposure level that could, upon averaging, be reduced below the MPE. Thus for smart meter emissions, a comprehensive determination of compliance with the FCC exposure rules includes assessing the average RF field across the dimensions of the body (spatial average) and the average over time (time average). In practice, and as found in virtually all of the certification reports filed with the FCC for smart meter emissions by manufacturers, a simplifying assumption is made that if the maximum, instantaneous field[12], without inclusion of time or spatial averaging, is compliant with the MPE, then no further evaluation is necessary. In this investigation, however, the issues of how duty cycle and spatial averaging can affect exposure assessment were addressed so that a more accurate assessment of compliance with the exposure rules could be performed; for both the time averaging and spatial averaging factors, potential exposures will be found that are less than maximum, instantaneous field values. The MPEs are based on the assumption of uniform exposure over the whole body; the non-uniform fields, common to real-world exposure, are normally spatially averaged to obtain the best estimate of an equivalent, uniform exposure. For convenience in interpreting the reported values of measured RF fields, measured RF fields are expressed in terms of a percentage of the public MPE; i.e., a value of 100% represents the exposure limit. The rationale for this approach is that the MPE varies with frequency and reporting of RF fields simply in terms of power density requires adjustment of the power density values to determine how the value compares to the actual limit for evaluating compliance. Note that the MPE varies across the 900 MHz license free band (by approximately 3%) and is also different for the 2.4 GHz license free band (approximately 66% different from the MPE for the 900 MHz band).

The MPEs listed in Table 2 are based on limiting the underlying basic restriction on RF energy absorption within the body, as averaged over the whole body, and on local tissue absorption. The energy absorption rate is referred to as the specific absorption rate (SAR) which is expressed in the unit watts per kilogram (W/kg) of tissue. The FCC MPEs, for general public exposures, are based on a whole-body averaged SAR limit of 0.08 W/kg with a local, peak SAR of 1.6 W/kg averaged over any one gram of tissue (defined as a tissue volume in the shape of a cube) except for the extremities (hands, wrists, feet and ankles) in which a local SAR of 4 W/kg averaged over any 10 grams of tissue is permitted. For occupational exposures, the FCC MPEs correspond to a whole body averaged (WBA) SAR of 0.4 W/kg with a local, peak SAR of 8 W/kg averaged over any one gram of tissue except for the extremities in which the SAR limit is 20 W/kg averaged over any 10 grams of tissue.

RF exposure limits are derived from a presumption that the resultant RF field, taking all possible polarization components of the field into account, complies with the

[12] The term instantaneous refers to the absolute peak magnitude of the RF field in the time domain, similar to the peak power of a radar pulse.

limit. The MPE values vary with frequency because of the frequency dependent variation of RF energy absorption of the body. The limits presume the possibility of the resultant magnitude of the RF field being oriented in such a way as to result in the greatest energy absorption possible within the body. Thus, the limits are, generally, conservative since such alignment of the polarization of the incident RF field with the body orientation during real world exposure is often not the case. Hence, for compliance assessments, relative to exposure limits, RF fields are to be measured such that the overall resultant magnitude of the field is obtained, regardless of the different polarization components that may exist. The RF field measurements accomplished in this project included the measurement of three mutually orthogonal polarization components and the formation of the resultant magnitude of the incident RF field.

Technical Approach Used in this Project

Technical Approach Used in this Project

RF Instrumentation Used in the Measurements

The principal measurement effort in this study was directed toward determining two things about the RF fields emitted by the GMP and BED smart meters: (a) the instantaneous peak magnitude of RF fields emitted by the meters and the (b) duty cycle of the various emissions. The very intermittent nature of the smart meter emissions as well as the fact that the emissions can occur over a range of frequencies requires an instrument that has both frequency resolution and brief signal capture ability. Broadband probes, commonly used for RF field exposure assessment, for smart meter measurements, suffer from two perspectives. They do not discriminate the frequency of the field that is causing a response of the instrument and they typically have response times that are entirely too long to be able to accurately measure the RF field during the very brief pulses of RF energy produced by smart meters. For example, a common response time of most broadband RF field probes is approximately one second. This means that the instrument requires that the signal (RF field) that is being measured must exist for at least one second before the meter response can reach the peak or full value of the field. For the typical emissions of smart meters of the type explored in this study, that are often less than 1/10 of a second in duration, this places a significant disadvantage on the broadband type of measurement instrument. Further, if the broadband probe has a flat frequency response (the output of the probe does not change with frequency for a constant RF field level), it cannot properly weight the detected RF field in accordance with the frequency dependence of the MPE. The MPE for RF emissions in the 900 MHz band are about 60% of the MPE values applicable to the 2.4 GHz band. Hence, the flat responding probe, while it may indicate the presence of pulses of RF field, will not accurately add up the RF fields across all frequencies to obtain a proper measure of the aggregate RF field relative to permissible exposure levels.

Because of the above instrumentation issues, a spectrum analyzer based detector was used for these measurements (Narda Selective Radiation Meter model SRM-3006, SN D-0069). Figure 5 shows the instrument which consists of a wideband probe/antenna (SN K-0242) that is connected to a spectrum analyzer base unit that is controlled with firmware that allows for measurement and display of detected RF fields.

This instrument permits display of the detected RF signals from the probe/antenna in the frequency domain so that the strength of any individual signal can be determined. Further, the probe/antenna contains a solid state switch that provides for a very fast sequential sampling of the measured RF field over the three axes of the probe/antenna elements. This allows for display of the resultant field magnitude as a function of frequency. Illustrative spectral displays of the RF LAN (900 MHz band) fields observed in front of the Elster and Itron smart meters are shown in Figures 6 and 7 respectively. These figures represent the capture of absolute peak values of momentary RF fields on any frequency emitted during the measurement period. The spectra shown in these figures develop over time since an RF emission on any specific frequency may only exist for an extremely brief period. The spectrum in Figure 7 shows the result of a less active meter over the measurement period. In practice, the RF field measurement data acquired during the many measurements of the project were stored in the digital memory of the SRM instrument and downloaded to a computer for subsequent further analysis and display.

A powerful feature of the SRM-3006 is that measurements can be displayed in alternative units of measure and, for these measurements, directly as a percentage of the FCC MPE for general public exposure, automatically adjusting the measured field for the frequency dependency of the FCC MPEs. Notice that the spectrum displays of RF fields (Figure 6 and 7) are presented against a logarithmically calibrated vertical scale of percent of the FCC's public MPE. With the instrument settings used in most measurements, the noise floor of the instrument, in terms of peak values, was less than 10^{-5} percent of the FCC public MPE (i.e., less than 0.00001% of the MPE).

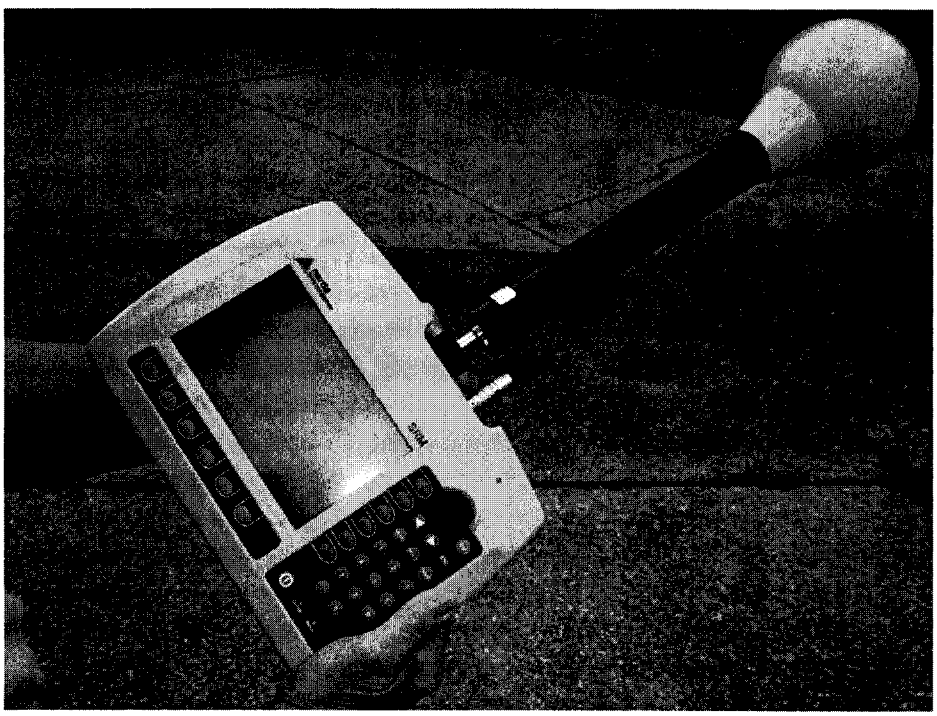

Figure 5. The Narda SRM-3006 Selective Radiation Meter is based on fast Fourier transform (FFT) spectrum analyzer technology and uses a probe/antenna to measure the absolute magnitude of incident RF fields across the frequency range of 26 MHz to 3,000 MHz and digitally converts the detected field to the equivalent percentage of the FCC MPE.

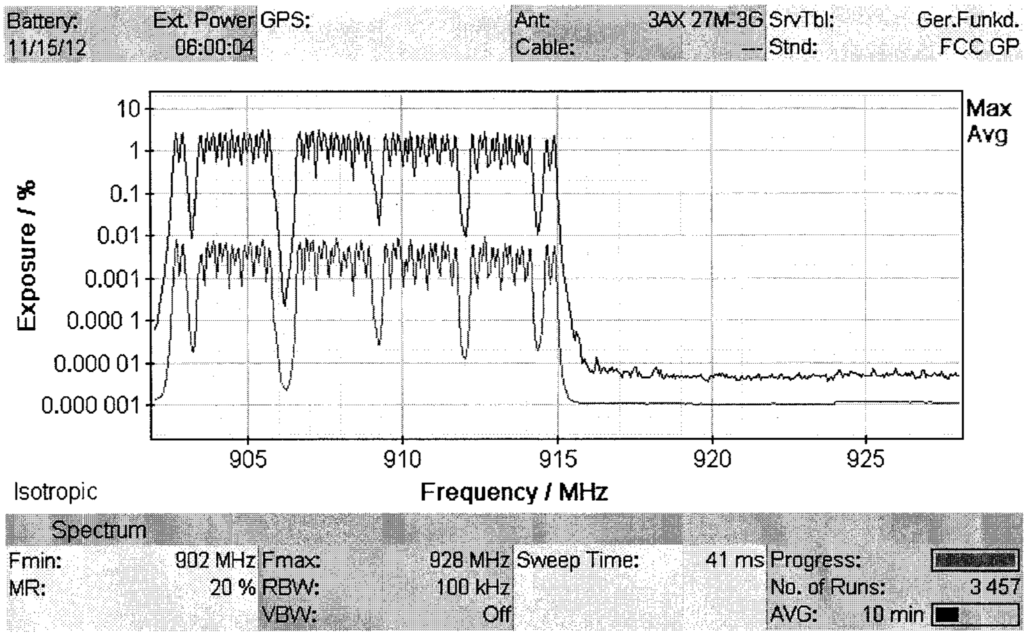

Figure 6. Illustrative maximum-hold RF spectrum display at one foot in front of a GMP smart meter showing the peak signal strengths of intermittent signals occurring randomly on 25 channels across the 902-915 MHz band during transmission of historical load profile data.

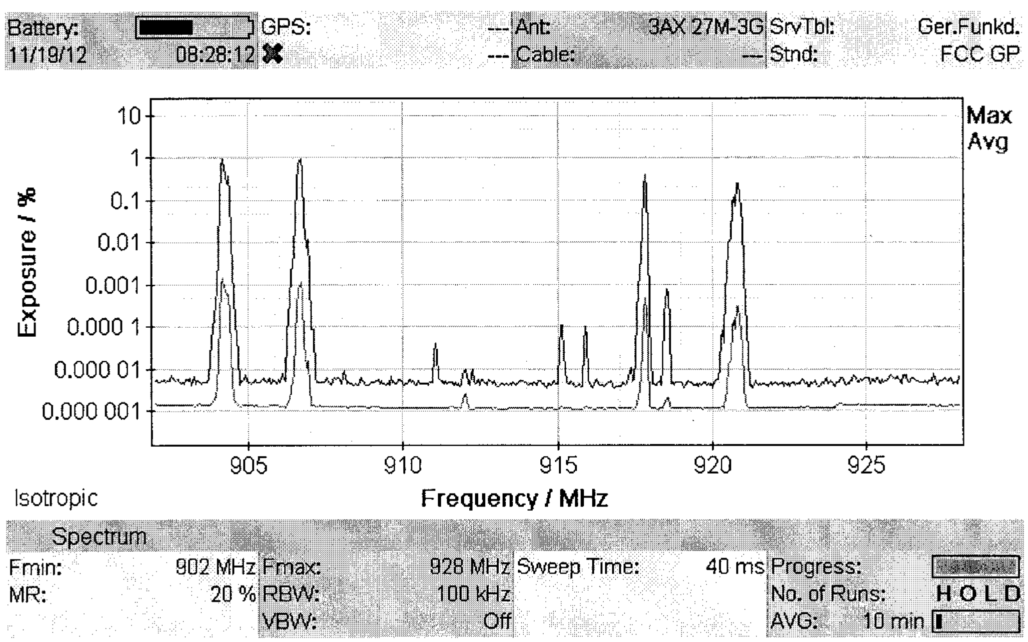

Figure 7. Illustrative RF spectrum display at one foot in front of a BED smart meter showing the peak signal strengths of intermittent signals occurring randomly across the 902-928 MHz band during transmission from a less active meter.

An additional feature of the SRM-3006 that made it particularly useful in this investigation was a scope or time-analysis mode in which the instrument can be tuned to a specific frequency with an adjustable resolution bandwidth (RBW) so that detected signals can be measured in the time domain. For pulsed RF fields that may have a fast rise time, a sufficiently wide RBW is necessary to properly detect the pulse. This facilitated capture of bursts of RF signals emitted by the smart meters. For the measurements performed in time-analysis mode, a RBW of 32 MHz (the widest possible on the SRM-3006) was used when centered on the specific signal frequency of interest. In this mode, the instrument becomes a "tuned oscilloscope" allowing observation and capture of the time domain waveform of RF signals within its RBW. The RBW may be thought of as a measure of the instrument's ability to discriminate two frequencies; the narrower the RBW, the better the instrument can show the presence of two frequencies that are close together. When used in time-analysis mode, however, wider RBWs permit detection of fast rise time pulses.

The SRM-3006, with accompanying probe/antenna, is capable of performing narrowband measurements of signals from 26 MHz to 3,000 MHz (3 GHz). For spectral measurements of the smart meter emissions, a RBW of 100 kHz was used for both the 900 MHz RF LAN signals as well as the 2.4 GHz HAN signals. The significantly wider RBW (32 MHz) was used for the time domain measurements to accommodate the fast rise time of the pulses. This value was deemed sufficient to allow accurate detection of the peak value of pulsed fields from the smart meter but was arrived at through evaluation of the indicated peak value of smart meter pulses with different RBWs.

For measurement of the 900 MHz band RF fields associated with the RF LAN emissions of smart meters, the instrument exhibited a sweep time of approximately 40 milliseconds (ms) for most of the measurements. During this period, measurements are made of the three polarization components of the RF field; the three values obtained at each frequency are assembled as the resultant value and the resulting spectrum is displayed on the instrument's screen. While this is a very fast process to accomplish this task, the capture of signals emanating from the meters which are only fleetingly present requires that the measurement process extend for a period sufficiently long to acquire a spectral display wherein the peak signal values are stable. As the pulsed fields on any given frequency across the band are only present for very brief periods, the challenge presented to the instrument is to sample each frequency where a signal exists for enough times that the displayed resultant field no longer changes over additional sweeps of the analyzer. When the spectral peaks no longer continue to increase in magnitude, the indicated resultant represents the true value of the peak RF field. Sampling for shorter durations can lead to an underestimate of the actual magnitude of the field since the analyzer may have not captured sufficient samples of the field strength on a specific frequency to insure that the peak value has been obtained. This means that most measurements, especially when they were not as frequent as at other times, required that the measurement might take as much as a minute or more to obtain a stable peak height of the signals. For the 900 MHz RF LAN fields, the typical emission (pulse) duration is in the range of 30 to 100 ms; this length of pulse is easily captured in terms of its peak value. For much shorter pulses, a different method is needed.

The approach used for evaluation of RF fields was, after acquisition of a spectrum of signal peaks (each peak representing the signal on a given frequency), to have the instrument identify the maximum peak value in terms of a percentage of the MPE. For all of the measurements reported here, only the greatest measured RF field from the spectrum of signals measured was used for assessing potential exposure. As the spectra shown in Figures 6 and 7 illustrate, there is typically some variation in the peak heights of the measured RF fields, i.e., not all peaks are exactly of the same magnitude. This variation can be related to the power output characteristics of the transceiver within the meters [9], the difference in MPE value at different frequencies, the possibility that not all spectral peaks were sufficiently sampled to arrive at a completely stable value for each peak and instrument measurement repeatability. Nonetheless, the maximum peak value from each measured spectrum was always used in the subsequent evaluation of fields.

For measurements of the HAN radio emissions, in the case of the GMP smart meters, an alternative method was determined to be necessary to capture meaningful measures of the resultant RF field magnitudes. Because of the very narrow pulses produced by the HAN radio, typically less than 2 ms, and the long period between each emission, the spectrum analyzer method of scanning across the entire frequency band was insufficient to allow collection of the resultant field magnitude due to the scan time being too long, even at 40 ms per scan. In this case, the SRM-3006 was configured in time-analysis mode with the center frequency of the analyzer placed on the fixed frequency produced by the HAN radio (although the HAN radio can operate over the entire band, it remains fixed during communication with an IHD or is simply attempting to connect with an IHD). In practice, at each site where HAN radio measurements were performed, the 2.4 GHz band was scanned to observe for the frequency at which the radio was transmitting. Once this frequency was identified, the instrument was then set to time-analysis mode, centered on the operating frequency of the HAN radio as observed from the spectrum measurement, and then adjusted to permit capture of the peak value of the emission by use of a 32 MHz RBW and fast sweep time. Even with this approach, each polarization component was measured separately to insure capture of the peak RF field. Data for the X, Y and Z probe axis readings were recorded for subsequent computation of the resultant magnitude of field.

Duty cycles were determined by the ability of the SRM-3006 to automatically indicate the duty cycle produced by time domain measurements over any period of time. A unique aspect of the instrument is its ability to collect RF field values across the time domain of a full 30 minutes but still respond to the momentary, very brief pulses presented by the smart meters. The duty cycle was calculated internally in the instrument as the ratio of the overall average power of the measured RF fields to the highest peak value of RF fields. For RF fields that are always exactly of the same amplitude, when they are present, this is equivalent to the ratio of the total signal on-time to the overall observation time.

Low Frequency Instrumentation Used in the Measurements

Although the prime effort in this study was that of characterizing the RF fields emitted by the GMP and BED smart meters, supplementary measurements were also performed of low frequency fields that might be associated with the operation of the meters. Such emissions, for example, could result from the use of switch mode power supplies within the smart meters to power the radios. Measurements of low frequency electric and magnetic fields were conducted in Colville with test meters provided by both GMP and BED using a Narda model EHP-50D electric and magnetic field analyzer (SN 000WX10510). This device, shown in Figure 8, provides for isotropic measurements with a dynamic range of 140 dB for electric and magnetic fields (depending on the specific configuration of the device). Internal to the sensor cube are three mutually orthogonal coil sensors for magnetic fields and three orthogonal sets of capacitor plates used as electric field sensors. Minimum detectable electric field strength is nominally 1 V/m and minimum magnetic field flux density is nominally 1 nanotesla (nT). The instrument is battery powered and is connected to a personal computer (PC) via an optical fiber cable for spectral analysis. Built-in fast Fourier transform (FFT) spectrum analysis allows evaluation of the frequency content of the electric and magnetic fields over the frequency range of 5 Hz to 100 kHz. Measured values of electric and magnetic field are displayed on the PC and saved to disc memory for subsequent analysis. Measurements with the EHP-50D were performed at a distance of 1 foot directly in front of each of the test meters. Electric and magnetic field spectra were measured across the 0 to 1 kHz, 0 to 10 kHz and 0 to 100 kHz frequency ranges.

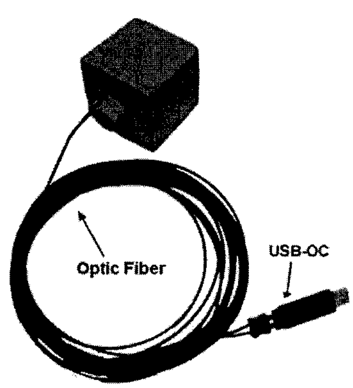

Figure 8. The Narda model EHP-50D Electric and Magnetic Isotropic Field Analyzer. The analysis of output from the sensor is performed via FFT in a connected laptop computer running special software.

Technical Approach Used in this Project

Background measurements of both electric and magnetic fields were made with each test meter unpowered for comparison to the measurements with the meters being powered up. All measurements were performed for a period of 2 minutes each to obtain the RMS value of fields detected by the probe. During these measurements, the smart meters were powered up but not connected to either an RF LAN or HAN IHD (in the case of the Elster meter).

Instrument Calibrations

Both the SRM-3006 and associated probe/antenna as well as the EHP-50D were used within 24 months of the respective instruments having been placed in service. Factory generated calibration certificates are provided in Appendix C for the SRM-3006 and Appendix D for the EHP-50D. The SRM system used in this project was calibrated by Narda on October 7 (probe) and October 13, 2010 (spectrum analyzer unit), but was not placed into service until February 22, 2011 (next factory calibration due February 22, 2013).

Prior to the measurements in Vermont, the SRM-3006 and associated probe/antenna were evaluated for their response to RF fields at 915 MHz, the center of the 902-928 MHz band in which the smart meter RF LANs operate, by comparing the indicated value of RF field to a similar probe/antenna (SN H-0368) that had been calibrated by Narda on October 27, 2011. The calibration certificate for the comparison probe is shown in Appendix E.

The probe/antenna comparison was performed in Colville, WA by positioning each probe at one foot directly in front of a test smart meter operating in the 900 MHz band, acquiring a spectrum of the observed smart meter emissions for approximately two minutes and, then, comparing the indicated value of the maximum peak RF field from the two units. This procedure yielded readings that differed by 6.5% in terms of percentage of the public MPE. This is equivalent to 0.27 dB, this value being well within the uncertainty of the manufacturer's calibration method of 1 dB. Through this quality assurance process, it was deemed that the SRM system as used for measurements in Vermont was in compliance with the manufacturer's stated specifications

How the Measurements Were Made

The measurements performed for this project were accomplished in the state of Vermont at installed smart meter sites, primarily residential locations, and in Colville, WA where measurements on test meters provided by both GMP and BED were conducted. The Colville measurements allowed for examining the time domain waveforms of the signals under alternative scenarios. For example, in the case of the GMP Elster meter, the HAN radio was used to connect with an IHD so that differences in RF performance could be observed.

Technical Approach Used in this Project

RF fields were measured as a function of distance from the front face of the meters in both Vermont and Washington from 1 foot to 10 feet from the meters as illustrated in Figure 9. Measurements were performed by holding the instrument probe/antenna at the height of the meter face, standing to the side as illustrated in Figure 9, with the probe/antenna perpendicular to the front surface of the meter face. A tape measure was used to locate the measurement distance relative to the front surface of the meter as well as adjusting the probe/antenna to the correct height.

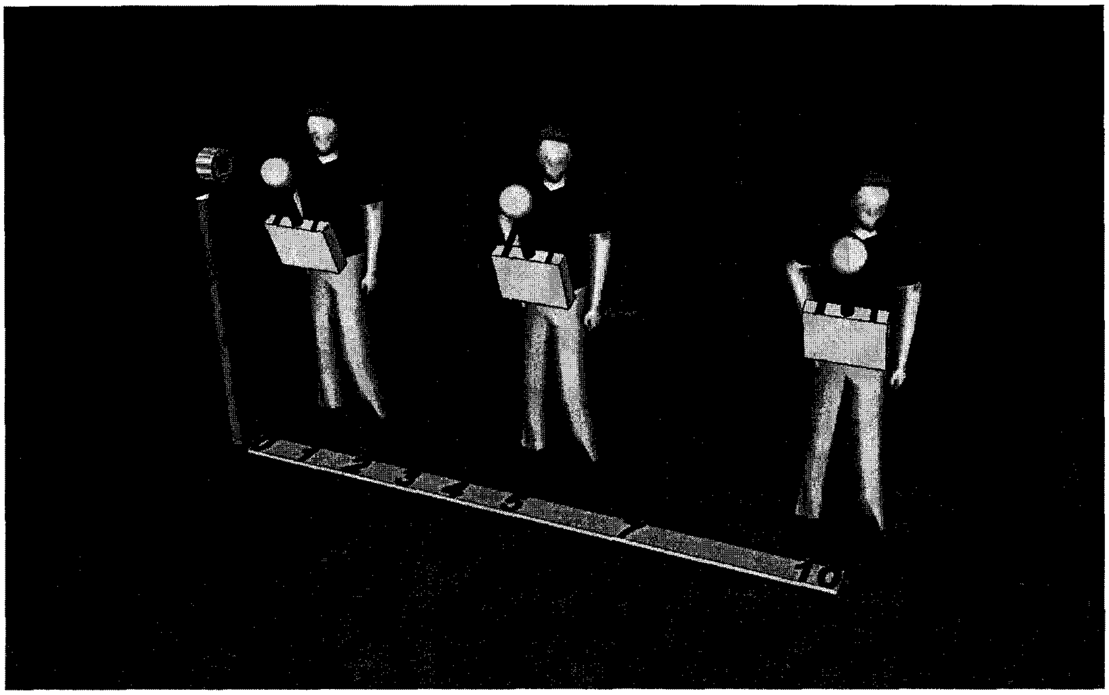

Figure 9. Illustration of the measurement of RF fields at different distances, ranging from one foot to 10 feet from the front surface of a smart meter.

At the Vermont sites, measurements were performed inside most of the buildings on which the meters were attached. RF fields as a function of height above ground were also measured in both Vermont and Washington. Measurements related to the directional properties of the meters were made in Washington. In Colville, there are no smart meter networks and, hence, the meters could not connect with a mesh network as they did in Vermont. Figure 10 shows measurements being made at a site in Burlington using the SRM-3006.

Figure 10. Measurement of RF fields in front of a residential smart meter installation. Measurements were made at distances from 1 foot to 10 feet in front of the meters.

For determining meter emission duty cycles, the SRM-3006 was supported on a tripod as shown in Figure 11 so that the probe could be held fixed in position for the 30-minute measurement periods typically used.

Measurement of Other Wireless Devices

During the indoor measurements of smart meter RF fields, on a few occasions, the opportunity to measure fields produced by other common devices occurred. Hence, measurement data were also collected near two microwave ovens and six wireless routers used for distribution of Internet connectivity.

Environmental RF Field Measurements

To help provide some perspective on the relative amplitude of smart meter RF fields, additional environmental measurements were made of signals produced by VHF FM radio and TV broadcast, UHF TV broadcast, and mobile phone base stations and a long range FAA air traffic control radar at 14 different sites within the state. Figure 12 illustrates these measurement locations within the state. Areas where measurements were performed included Rutland, Burlington, Montpelier and Saint Albans, Vermont. To facilitate rapid measurement of RF fields in many locations, a portable, spectrum analyzer based instrumentation system that could be used with a vehicle was determined as the most practical approach for acquiring data. These measurements were made from a vehicle with the SRM-3006 probe/antenna connected to the analyzer via a 1.5 meter long cable and held with a 24 inch PVC pipe to support the probe/antenna above the roof level of the vehicle. All measurements were performed with the vehicle stopped and turned off.

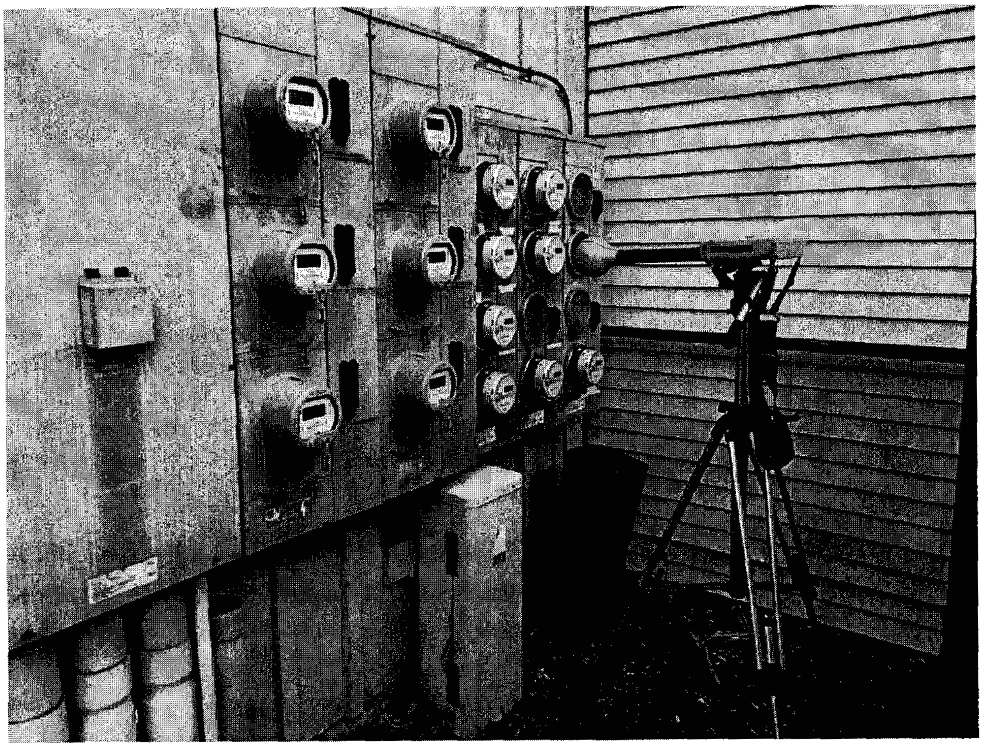

Figure 11. Use of the SRM-3006 to measure the duty cycle of smart meter emissions over a 30-minute period at a meter bank in Rutland.

Technical Approach Used in this Project

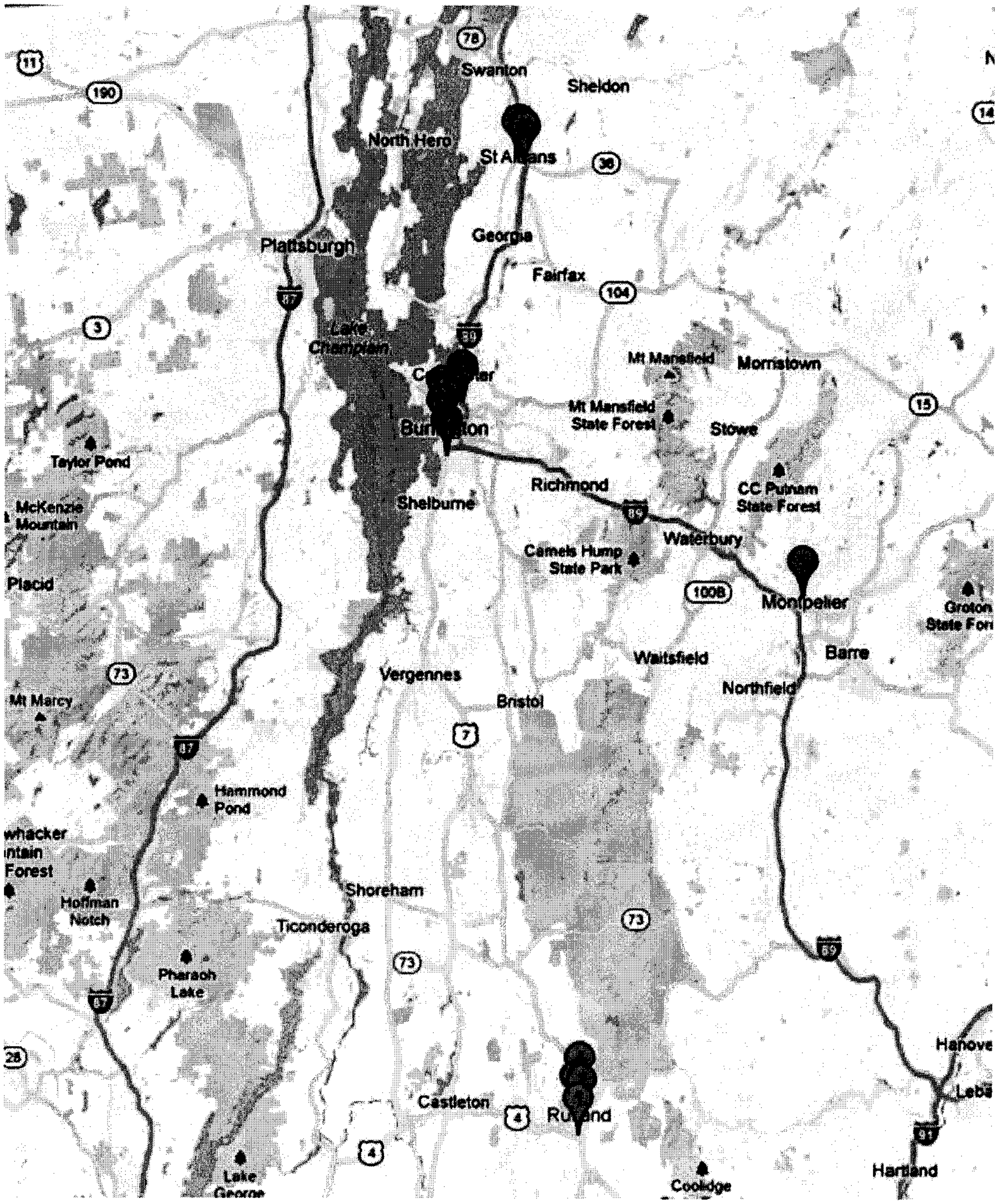

Figure 12. Environmental RF measurement locations within Vermont included in the study.

Results

Results

RF Fields of Smart Meters vs. Distance

Field measurements were made no closer to a smart meter than 1 ft (0. 3m). IEEE Standard C95.3-2002 [10] recommends a minimum measurement distance of 0.2 m to minimize nearfield coupling and field gradient effects when using common broadband field probes. Measurement data can be distorted when using an isotropic probe to measure steep spatial gradients close to a radiating element of a smart meter. These gradients can lead to considerable variation of the indicated amplitude of the field being measured over the volume of space occupied by the measurement probe elements. Nearfield coupling, and associated erroneously high field readings, can be particularly troublesome when employing field probes in the reactive near field that are comparable to the size of the source antenna. The elements inside the SRM-3006 probe/antenna are approximately 10 cm long. Based on the potential for significant probe nearfield coupling with the smart meter internal transmitting antenna, measured values with surface contact between the probe/antenna and a smart meter should be avoided and considered likely substantial over-estimates of the true field. It was deemed appropriate that the minimum distance at which fields would be measured with the SRM-3006 should be one foot. A distance of one foot (~0.3 m) is equivalent to approximately one wavelength at 915 MHz.

The process of measuring smart meter RF emissions was facilitated by instructing each meter to transmit in the 900 MHz band during the measurement period. Since most of the time there is only intermittent activity from smart meters, performing reliable field strength measurements can be problematic since the emissions, when they do occur, are so brief. In the measurements in the GMP service territory, GMP assisted with the process by providing access to a device which could be used to "ping" the specific meter being measured. The device, variously called a field service unit, can issue wireless signals directed to the meter and cause the meter to respond by sending an acknowledgment and data. This method insured that when the RF field measurements were made, there was sufficient signal activity to allow for an accurate capture of the instantaneous peak field magnitudes. The device, a Radix model FW-950, is a handheld portable computer equipped with a 900 MHz band radio and associated software that provides communication with the smart meter. By invoking a "continuous ping" feature on the FW-950, smart meter transmitter activity could be started and this procedure was used during the measurements of the GMP meters. To insure that the measurement process was not "contaminated" by any signal sent from the FW-950 to the smart meters, the device was kept typically about 50 feet from the smart meters being measured.

While the on-site use of the field service unit was used with the GMP meters in the Rutland area, an alternative approach to insuring smart meter transmission was pursued with the BED meters in Burlington. The BED issued commands from their network head-end at the utility headquarters over the network to invoke a response from the meter targeted for measurements. This required relaying the meter network number to personnel at the utility via a mobile phone. BED technical staff accompanying the measurement team attended to this task prior to each set of measurements. Once the request for transmission was issued from the network head-end, it would typically take a few seconds for the request to be received by the smart meter before it began its transmission response. A field service unit was provided by GMP to facilitate measurements on the GMP test meter sent to Colville. In the case of the BED test meter, once powered up, the meter begins to issue 900 MHz band signals as a means of "discovering" a smart meter network to which it can connect. These signals, while not present as often as those elicited for the GMP meter, served for the measurements of the Itron meter in Colville.

Peak RF fields, obtained at the various smart meter locations, expressed as a percent of the FCC MPE for general public exposure, are tabulated for the different distances at which measurements were made in Table 3 for the GMP and BED meters. The designation 'T' refers to the test meters provided by both GMP and BED for testing in Colville, WA. Measurements at a distance of 10 feet were not possible at GMP site 11 and BED site 3 due to nearby obstructions.

Table 3. Peak 900 MHz RF field magnitudes obtained at different individual smart meter sites in the GMP (Rutland) and BED (Burlington) service territories. These values represent the greatest instantaneous RF field observed at any frequency within the 902-928 MHz band and are expressed as a percentage of the FCC MPE for public exposure. The 'T' designates test meters measured in Colville. Data for sites at meter banks, GateKeepers and Cell Routers are shown elsewhere.

	Distance (ft) from meter face						
Site	1	2	3	4	5	7	10
GMP-1	3.540	1.146	0.492	0.304	0.179	0.093	0.020
GMP-2	3.533	0.945	0.145	0.283	0.136	0.079	0.012
GMP-4	1.325	0.536	0.305	0.109	0.034	0.076	0.046
GMP-5	3.924	1.312	0.586	0.342	0.204	0.224	0.078
GMP-6	3.097	0.756	0.508	0.461	0.284	0.146	0.087
GMP-7	2.462	0.976	0.588	0.250	0.277	0.081	0.046
GMP-9	1.190	0.408	0.161	0.087	0.118	0.063	0.033
GMP-10	2.566	1.134	0.183	0.214	0.083	0.076	0.049
GMP-11	1.532	0.423	0.231	0.130	0.089	0.053	
GMP-T	1.300	0.276	0.183	0.065	0.055	0.016	0.010
BED-2	0.863	0.097	0.059	0.101	0.038	0.029	0.00716
BED-3	0.982	0.434	0.259	0.316	0.173	0.056	
BED-4	0.564	0.162	0.051	0.040	0.092	0.042	0.017

Results

Table 3 continued.							
BED-5	0.355	0.184	0.076	0.041	0.028	0.043	0.0096
BED-7	0.263	0.149	0.036	0.060	0.026	0.027	0.104
BED-8	2.498	0.351	0.386	0.127	0.103	0.100	0.029
BED-T	1.356	0.373	0.255	0.193	0.119	0.046	0.030

The data in Table 3 are graphically displayed in Figures 13-14 for the Rutland area meters (linear and logarithmic plots). Variations in the measured value of fields are expected to be caused by measurement uncertainty and the real-world presence of uneven ground over which the measurements were performed and nearby objects that undoubtedly introduced ground reflections and scattering of RF fields that resulted in the observed variations in field values. Figure 15 plots the mean values of individual smart meter fields with plus and minus one standard deviation of measured values at each distance for the nine sites Vermont sites.

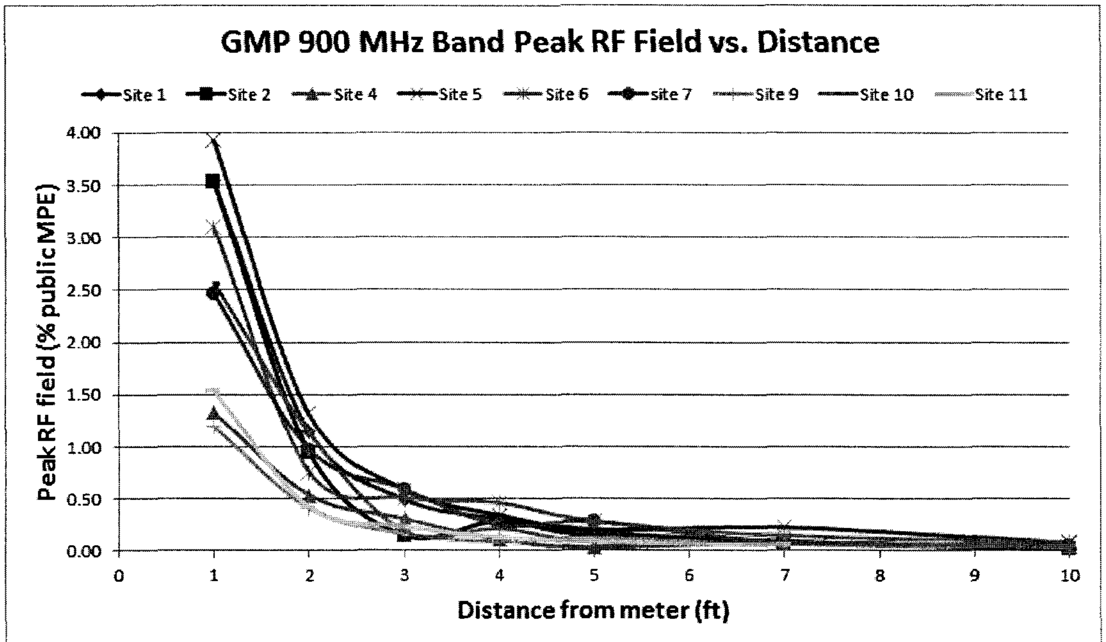

Figure 13. Linear display of measured peak values of RF fields at distances up to 10 feet in front of individual smart meters operated by GMP.

Results

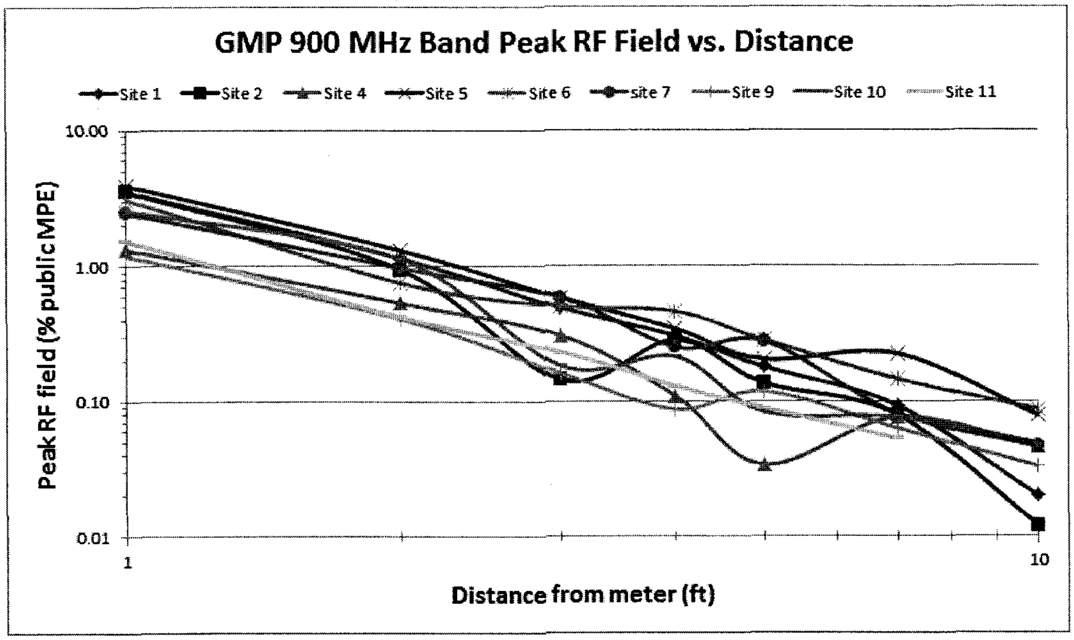

Figure 14. Logarithmic display of measured peak values of RF fields at distances up to 10 feet in front of individual smart meters operated by GMP.

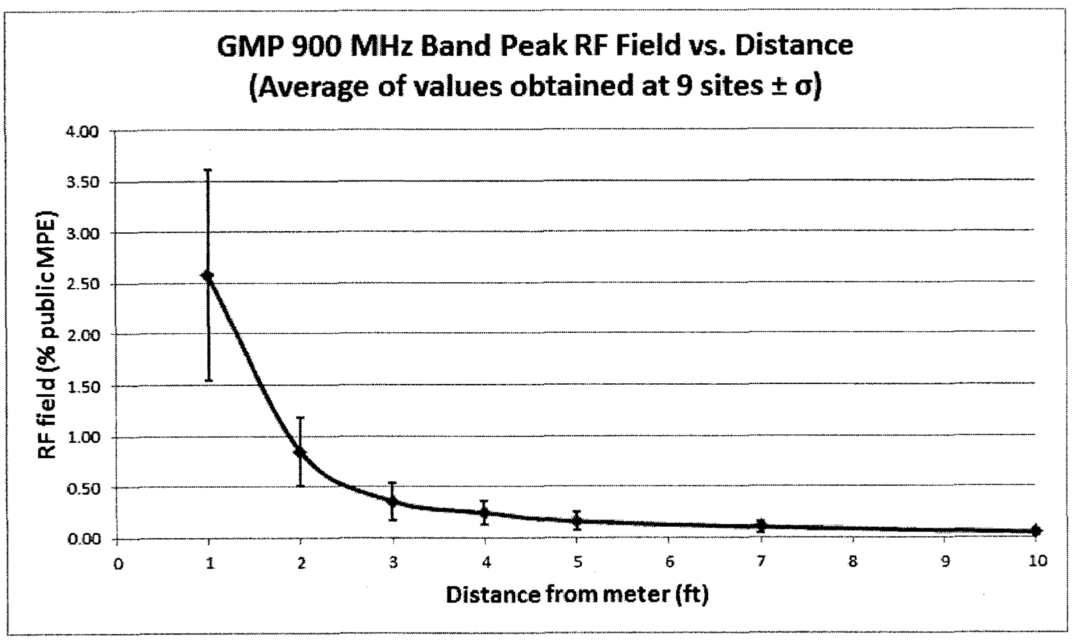

Figure 15. Average of 900 MHz band peak RF fields vs. distance ± 1 standard deviation of values obtained at nine individual smart meter sites in the GMP Rutland area.

Results

Similar graphical plots of RF fields obtained near individual BED smart meters in Burlington are provided in Figures 16 and 17 (linear and logarithmic plots). Figure 18 shows a plot of the mean values with the standard deviations at the six sites.

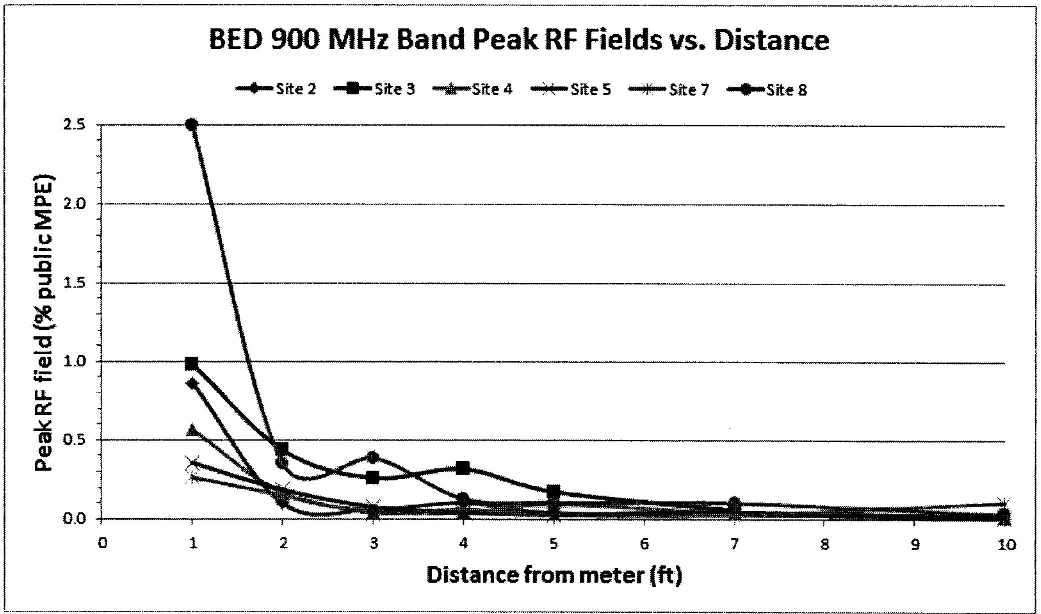

Figure 16. Linear display of measured peak values of RF fields at distances up to 10 feet in front of individual smart meters operated by BED.

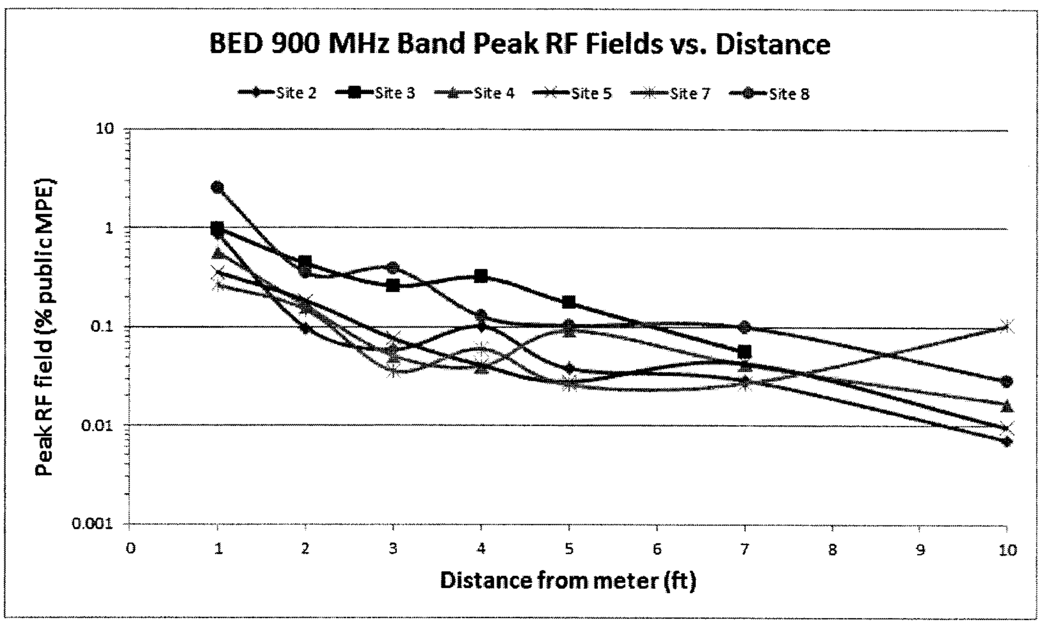

Figure 17. Logarithmic display of measured peak values of RF fields at distances up to 10 feet in front of individual smart meters operated by BED.

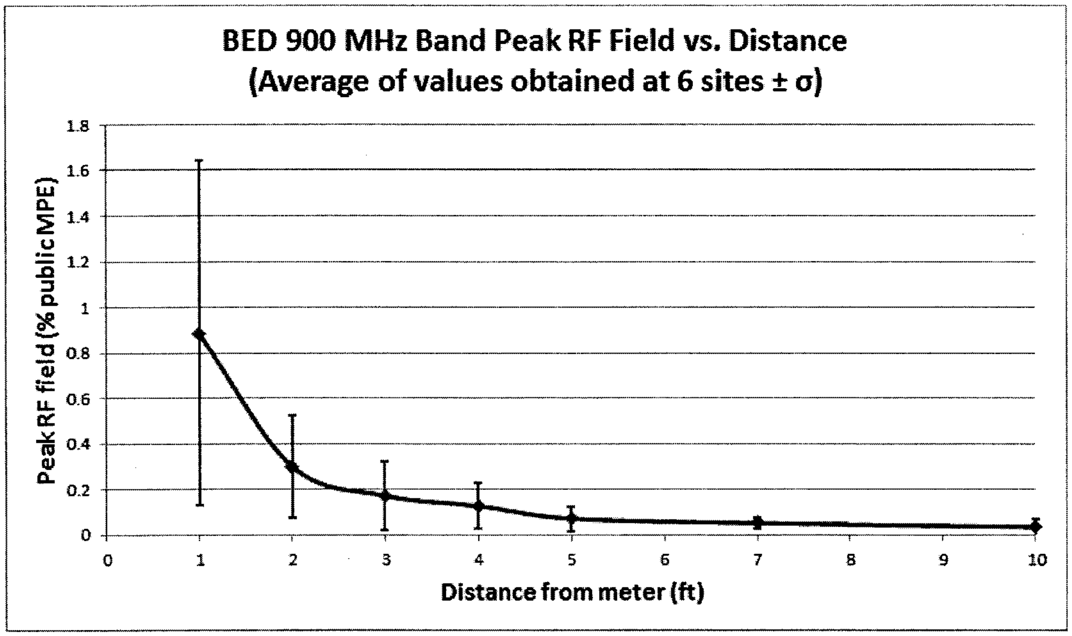

Figure 18. Average of 900 MHz band peak RF fields vs. distance ± 1 standard deviation of values obtained at nine individual smart meter sites in the BED service territory.

Separate measurements of RF fields were performed on two test meters shipped to Colville by GMP and BED. Figure 19 shows the variation of measured peak RF fields vs. distance for these two meters.

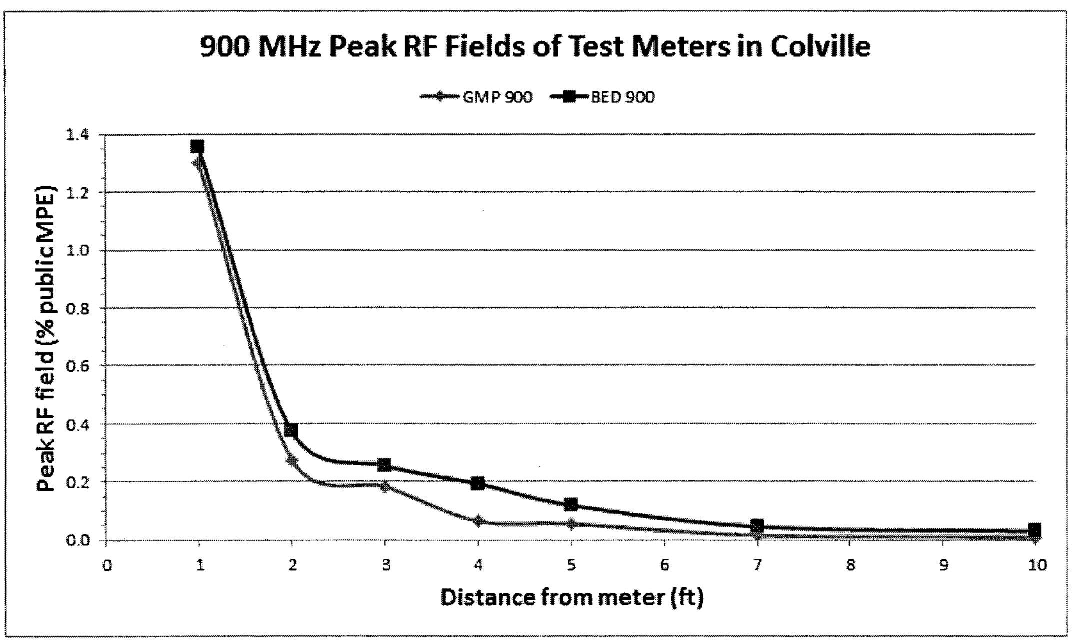

Figure 19. Measured peak RF fields produced by the Elster and Itron test meters in Colville, WA.

Results

RF fields associated with 900 MHz band emissions from a total of five different meter banks (collections of more than one meter) were also measured. Field variation with distance was measured at two of the locations while duty cycles were measured at four of the five sites. The variation of field with distance was determined by centering the meter on one of the meters in the bank and increasing the distance from that meter. The results for the two meter banks at which this was accomplished in the BED service territory are shown in Figure 20. It is noted that BED site 10 was inside a large closed, below ground electrical room (Figure 21) with irregular interior walls.

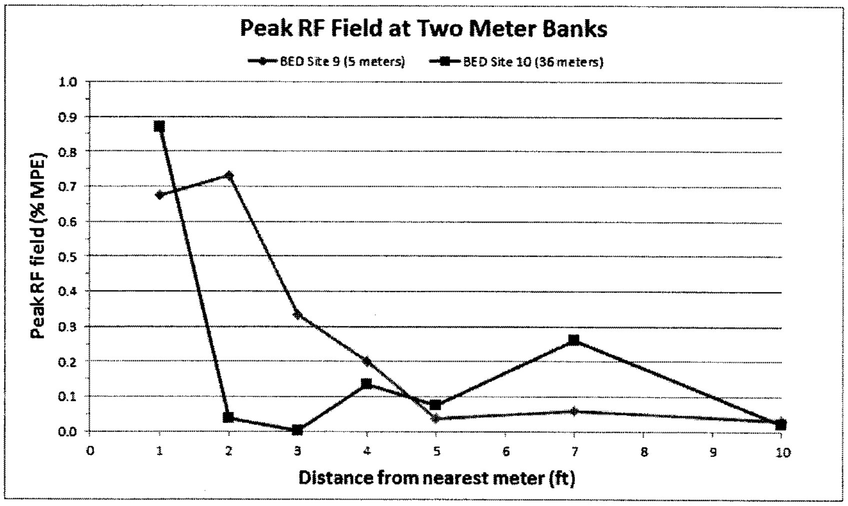

Figure 20. Measured peak RF fields of 900 MHz emissions observed at two meter banks (one with 5 meters and the other with 36 meters) in the BED service territory.

Figure 21. BED site 10 with 36 smart meters inside an electrical room.

Results

Implementation of the HAN radio feature by either GMP or BED for routine customer use had not occurred as of the time that this study was performed. GMP had established approximately 500 residential locations within their Rutland regional service territory as experimental sites to test the capability of the HAN system and explore customer reaction to the in home display (IHD). Whether all of those customers had "paired" the IHD with their smart meter to be able to see their electrical energy consumption was not known at that time. BED had not made any use of the HAN system as of the time of the project field work in Vermont. Despite the fact that the Elster meters used by GMP were not generally "activated" to interact with IHDs, the HAN radios in the smart meters periodically issue a very brief signal lasting approximately 1.75 ms once every 15 seconds plus a group of four closely spaced signals once per minute for a total of eight pulse emissions per minute. These signals are presumably related to the HAN radio searching for IHDs in the vicinity that have been commissioned to wirelessly connect to the meter. This characteristic of the HAN radios in the Elster meters means that one expects to observe periodic pulsed signals from the radio even if there is no IHD in range; in the case of multiple meters located together, as in a meter bank, more pulsed signals should be observed over time simply due to the greater number of meters, each sending out a periodic signal.

The time domain characteristics of the HAN (ZigBee) radio signal are the subject of a later section in this report. Measurements at BED smart meter sites during the project as well as work with the BED test meter in Colville did not reveal any HAN radio transmission activity.

Measured peak values of the RF field of the HAN radio in the vicinity of nine GMP smart meter sites, each composed as the resultant of the three orthogonal polarization components of the detected fields, are tabulated in Table 4. The resultant peak values are displayed graphically in linear and logarithmic format in Figures 22 and 23. Figure 24 illustrates the mean value of the measured peak HAN RF fields at each distance with the associated standard deviation of values obtained at nine GMP sites.

Table 4. Peak 2.4 GHz RF field magnitudes, associated with the HAN (ZigBee) radio, obtained at nine residential smart meter sites in the GMP (Rutland) service territory. These values represent the instantaneous RF field observed at any frequency within the 2.4 to 2.5 GHz band and are expressed as a percentage of the FCC MPE for public exposure. A 'T' designates measurements of the GMP test meter in Colville. Sites not listed here included nonresidential locations or locations where interior measurements were not conducted.

	Distance (ft) from meter face						
Site	1	2	3	4	5	7	10
GMP-2	0.276	0.21	0.05495	0.03912	0.03639	0.01948	0.00524
GMP-4	0.075	0.03836	0.07782	0.05009	0.04596	0.02047	0.01647
GMP-5	0.311	0.078	0.0273	0.0369	0.02981	0.00459	0.0037

Table 4 continued.							
GMP-6	0.311	0.06291	0.074	0.03879	0.02024	0.00848	0.00847
GMP-7	0.545	0.212	0.0867	0.04518	0.01215	0.02555	0.00765
GMP-9	0.254	0.139	0.11	0.04917	0.03597	0.0317	0.01264
GMP-10	0.51685	0.071	0.03448	0.01325	0.01436	0.01418	0.00689
GMP-11	0.317	0.16076	0.04742	0.01115	0.01052	0.00928	
GMP-13	0.18	0.00359	0.011	0.00047	0.00124	0.00192	0.00419
GMP-T	0.255	0.085	0.081	0.043	0.01322	0.01346	0.00936

RF Field Variation vs. Height above Ground

A comprehensive assessment of compliance with the FCC RF exposure rules includes an evaluation of the spatial average value of RF field over the dimensions of the body. The IEEE [7] provides guidance on this process.[13] In accord with this guidance, fields were measured over six-foot vertical lines at a lateral distance of one foot from the front surface of the 900 MHz band GMP and BED smart meters as well as the 2.4 GHz GMP meter with an active HAN radio. Spatially averaged fields, while less than the spatial maximum, more accurately correspond with the limiting energy absorption rates (SARs) of the body upon which the exposure limits are specified by the FCC.

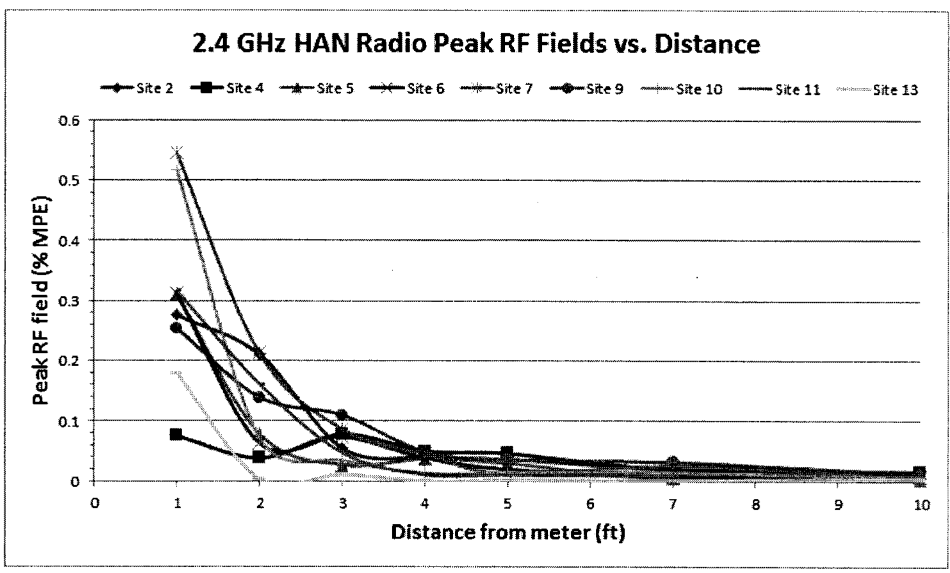

Figure 22. Linear display of measured peak 2.4 GHz RF fields of the HAN radio at GMP smart meters observed at nine individual meter sites.

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[13] From IEEE [7]: The spatial average is measured by scanning (with a suitable measurement probe) a planar area equivalent to the area occupied by a standing adult human (projected area). In most instances, a simple vertical, linear scan of the fields over a 2 meter height (approximately 6 feet), through the center of the projected area, will be sufficient for determining compliance with the MPEs.

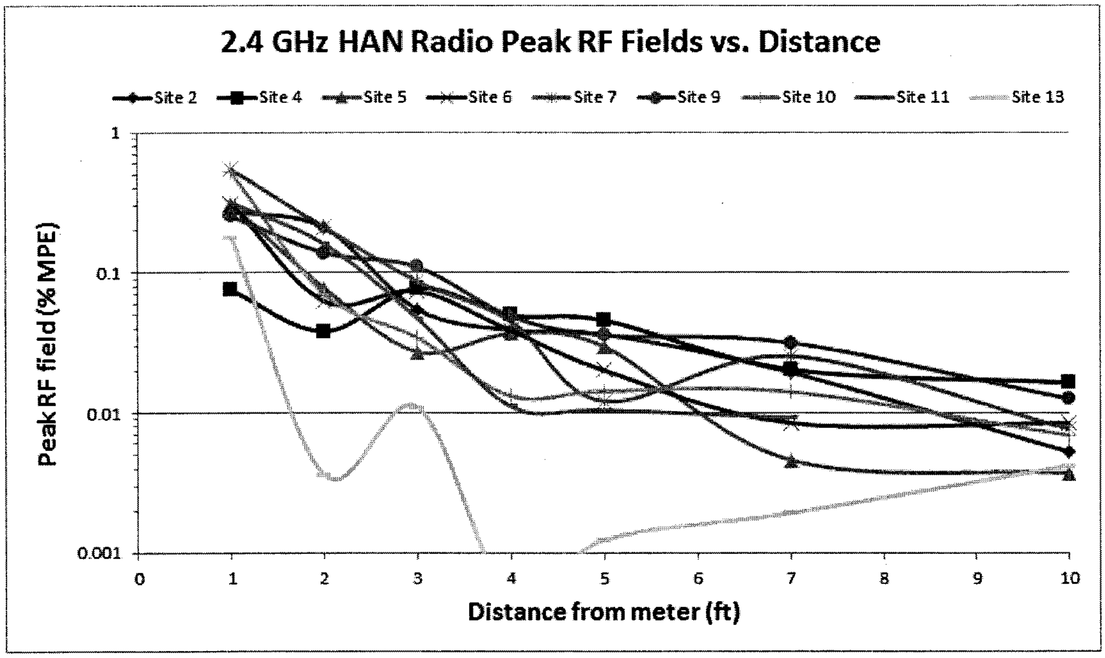

Figure 23. Logarithmic display of measured peak 2.4 GHz RF fields of the HAN radio at GMP smart meters observed at nine individual meter sites.

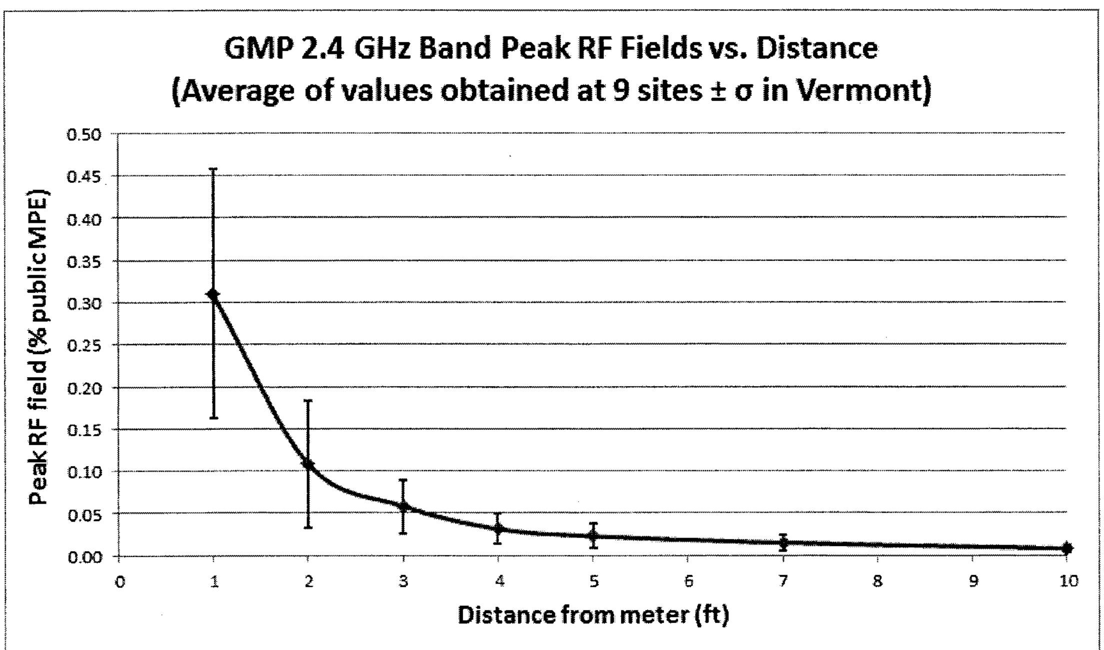

Figure 24. Average of 2.4 GHz band peak RF fields vs. distance ± 1 standard deviation of values obtained at nine individual smart meter sites in the GMP service territory.

Results

Figure 25 displays the 900 MHz band measurement results obtained near a GMP Elster meter for determining the vertical spatial average value of RF fields where the values have been normalized to a value of unity representing the greatest value at any height above ground. Figure 26 shows that the overall spatial average of peak RF field, expressed as a fraction of the FCC MPE, is 30.4% of the spatial maximum.

A similar set of measurement data shown in Figure 26, but for a different meter mounting height for the two test meters in Colville, show a consistent observation of the maximum field being associated with the mounting height of the meter. Spatially averaged RF fields of 36.3% and 48.9% of the spatial maximum values were measured. With both meters mounted at the same height, the results suggest a somewhat different distribution of RF fields in the elevation plane.

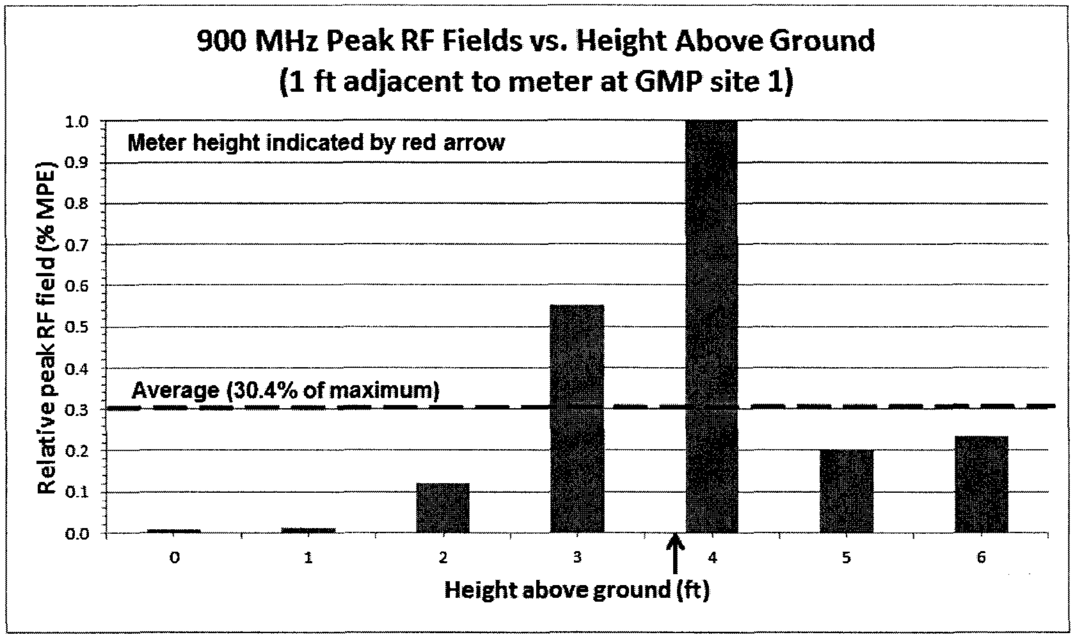

Figure 25. Relative peak RF field (as a percent of the MPE) vs. height above ground at one foot in front of a 900 MHz Elster meter operated by GMP in Vermont. Measured fields were normalized to the greatest value determined from all measurements. Overall, the spatial average was found to be 30.4% of the spatial maximum value. The variation in relative values is due to the fact that the smart meter emissions are mainly directed horizontal to the meter.

Results

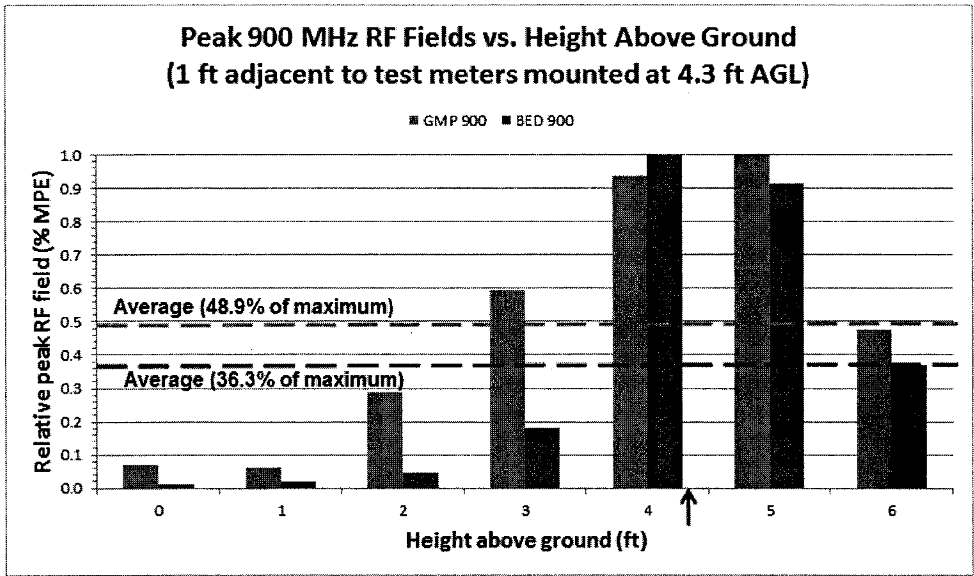

Figure 26. Relative peak 900 MHz band RF field (as a percent of the MPE) vs. height above ground at one foot in front of the Elster and Itron test meters in Colville, WA. Measured fields were normalized to the greatest value determined from all measurements.

The vertical spatial variation of 2.4 GHz peak RF fields of the HAN radio in front of the Elster meter is shown in Figure 27 where the spatially averaged RF field was 34.9% of the spatial maximum observed near the mounting height of the meter.

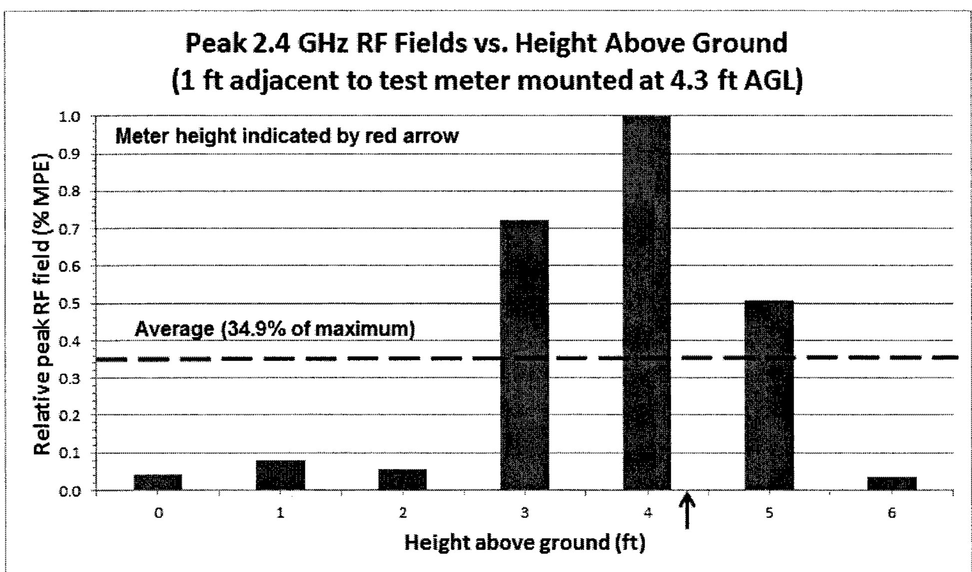

Figure 27. Relative peak 2.4 GHz band RF field (as a percent of the MPE) vs. height above ground at one foot in front of the Elster test meters. Measured field was normalized to the greatest value determined from all measurements.

Results

Azimuthal Directivity

Beyond variation of RF fields in the elevation plane, measurements were also performed to examine the directional properties of the smart meter emissions in the azimuth (horizontal) plane near the smart meters. The meters were installed in a standard electrical meter socket, powered up and, with the SRM-3006 and probe/antenna supported on a tripod, the peak RF fields were measured. The smart meter positioned in four directions: 0° (face of the meter facing the probe/antenna), 90° (smart meter facing to the left), 180° (smart meter facing to the rear and away from the probe/antenna) and 270° (smart meter facing right). These relative pattern data are shown in Figure 28. For both meters, including the 900 MHz and 2.4 GHz bands, the weakest RF fields were found to the rear of the meter, ranging from approximately 6% to 8% of the maximum value. This is the side of the meter that would typically face the exterior wall of a residence. For the 900 MHz emissions, the strongest RF fields were always from the front of the meter with lesser values to the sides and to the rear. RF fields of the 2.4 GHz HAN radio, however, were observed to be as much as 27% stronger off to one side of the meter as directly from the front.

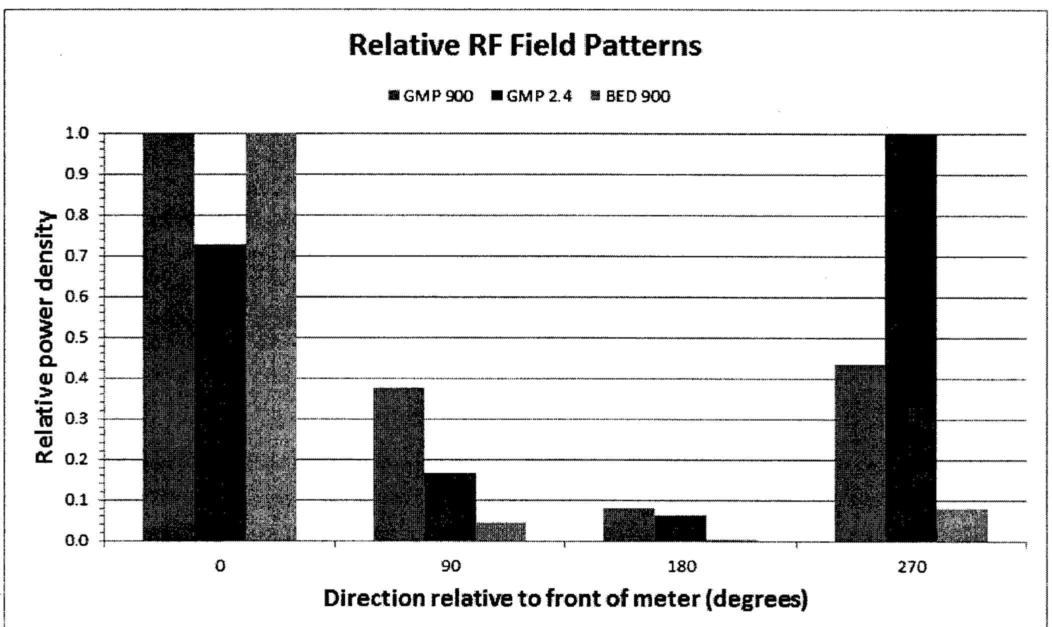

Figure 28. Relative RF field patterns in the azimuth plane for the GMP and BED 900 MHz radios and the GMP 2.4 GHz HAN radio. Generally, RF fields to the rear of the meters are weakest, being between approximately 6% and 8% of the maximum values.

Results

Interior RF Measurement Results

An important aspect of this project was determining the magnitude of smart meter RF fields found inside of residences equipped with smart meters operated by both GMP and BED. This process involved a similar approach as used for the exterior field vs. distance measurements. The respective meters were "pinged", either via the field service unit in the GMP territory or via the network in the BED area, and different rooms within each residence were scanned with the SRM-3006 to acquire a spectrum of the RF emissions. The maximum values were extracted from the saved spectral data as the value representative of potential exposure within the room. For interior measurements of the GMP HAN radio emissions, time domain measurements of the separate X, Y and Z polarization component fields were acquired by standing within the room, toward the center of the room where accessible, and capturing the narrow pulses that were relatively infrequently emitted. In this instance, the room was not spatially scanned since the acquisition of a meaningful measure of the RF field magnitude required the three polarization measurement values to be obtained at the same point in space.

A total of 141 interior RF field measurements (RF LAN and HAN emissions from GMP meters) were made between those in the Rutland area and in Burlington. The 900 MHz band measurement results are tabulated for the GMP and BED service territory homes in Tables 5 and 6 respectively. Interior RF fields associated with the operation of the 2.4 GHz HAN radios of the GMP meters are tabulated in Table 7. Collectively, the interior residential measurements yielded a maximum peak value of RF field of 0.08% of the MPE for public exposure, an average peak value of 0.0033% of the MPE and a minimum value of 0.00001% of the MPE.

Figure 29 shows the results of a cumulative percentile analysis of the interior peak RF field measurements. The median value of peak field was 0.00019% of the MPE. The horizontal axis of this figure represents the percent of all measurements having values equal to or less than the values on the vertical axis. For example, 40 percent of the measurements had values of peak RF field equal to or less than 0.0001% of the FCC MPE.

Results

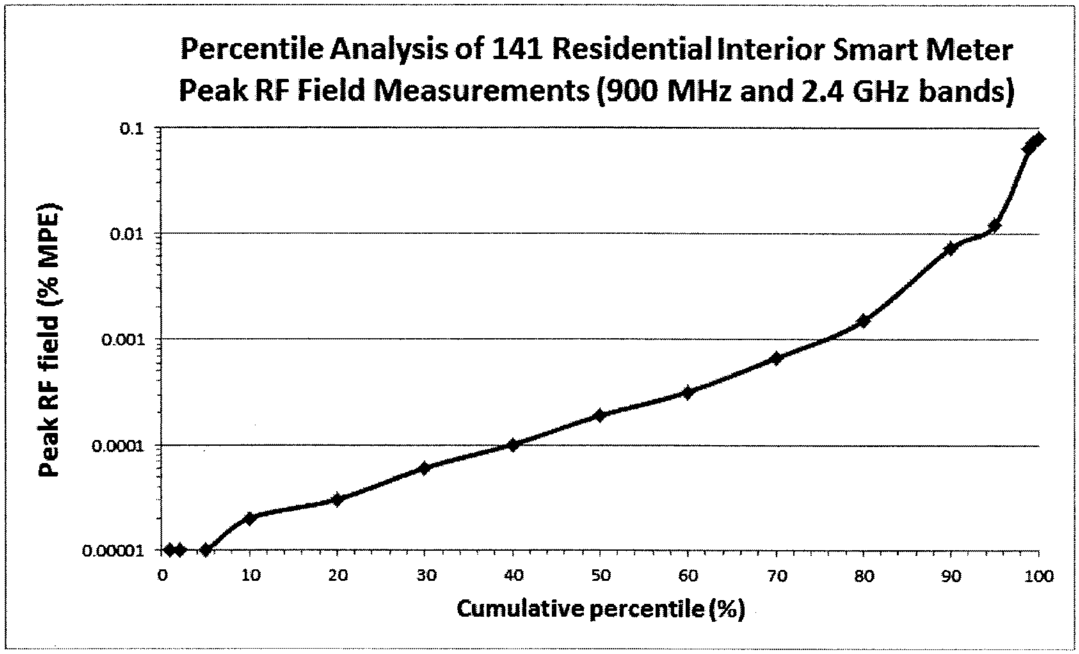

Figure 29. Percentile analysis of 141 residential interior field measurements of the instantaneous peak RF field as a percentage of the FCC MPE for public exposure performed in Rutland and Burlington, VT residences.

Results

Table 5. Summary of interior 900 MHz RF field measurements in residences in the GMP Rutland service territory (values in terms of instantaneous peak RF field as a percent of the FCC MPE for public exposure). Shaded cells represent rooms that were either not present at the site or were unavailable for measurement at the time of the visit.

Location	Site 2	Site 4	Site 5	Site 6	Site 7	Site 9	Site 10	Site 11
Inside Garage	0.00752	0.080	0.00038	0.024	0.00003			
Inside Living Room	0.07	0.00341	0.00935	0.00005	0.00071	0.00005		0.00055
Inside Dining Room			0.00029		0.016		0.00009	
Inside Family Room			0.00156	0.00009	0.00022			0.00003
Inside Kitchen	0.0033	0.00083	0.0001	0.00015	0.00015	0.00553	0.00067	0.00127
Inside Basement						0.00002		
Inside Master BR	0.00735	0.00439	0.00375	0.00315		0.00003	0.00306	0.00007
Inside BR1	0.00009	0.00056	0.00013	0.00025		0.00004		0.00002
Inside BR2	0.00039	0.012	0.00009	0.00025				0.00003
Inside BR3				0.011				
Inside BR4				0.00093				
Inside Office	0.00032	0.055		0.00029			0.00005	
Inside enclosed porch						0.038		
Utility Room							0.011	0.00505

Results

Table 6. Summary of interior 900 MHz RF field measurements in residences in the BED service territory (values in terms of instantaneous peak RF field as a percent of the FCC MPE for public exposure). Shaded cells represent rooms that were either not present at the site or were unavailable for measurement at the time of the visit.

Location	Site 2	Site 3	Site 4	Site 5	Site 7	Site 8	Site 9
Inside Garage		0.00133				0.00067	
Inside Living Room	0.00754				0.00091	0.00006	0.00069
Inside Dining Room	0.00038	0.022		0.00001	0.00004	0.00004	0.00003
Inside Family Room		0.0001					
Inside Kitchen	0.00019	0.0005	0.00034	0.00001	0.00011	0.00028	0.00001
Inside Basement							
Inside Master BR	0.00003	0.00002	0.0007	0.00001	0.00002	0.00002	0.00001
Inside BR1	0.00041	0.00006			0.00012	0.00007	0.00021
Inside BR2	0.00007	0.00042			0.00012	0.00006	
Inside BR3		0.00017					
Inside BR4							
Inside Office	0.00003			0.00003			
Inside enclosed porch							0.00011
Utility Room							

Results

Table 7. Summary of interior 2.4 GHz HAN radio RF field measurements in residences in the GMP Rutland service territory (values in terms of instantaneous peak RF field as a percent of the FCC MPE for public exposure). A * indicates that the home had an active HAN radio that was communicating with an IHD. Shaded cells represent rooms that were either not present at the site or were unavailable for measurement at the time of the visit.

Location	Site 2	Site 4*	Site 5	Site 6	Site 7	Site 9	Site 10	Site 11*
Inside Garage	0.00033	0.00149	0.00001	0.00008	0			
Inside Living Room	0.00078	0.0071	0.00417	0.00002	0.00007	0.00016		0.00152
Inside Dining Room							0.00002	
Inside Family Room			0.0001		0.00002			0.00037
Inside Kitchen		0.00294	0.00007	0.00001	0.00025	0.00008	0.00005	
Inside Basement		0.00142		0.00001		0.00003		
Inside Master BR	0.00023	0.0003	0.00013	0.00003		0.00002	0.00005	0.00031
Inside BR1	0.00007	0.00055	0.00002	0.00387		0.00001		0.00032
Inside BR2	0.00023	0.00034	0.00002	0.00128				0.00929
Inside BR3				0.00009				
Inside BR4								
Inside Office	0.00017			0.00004			0.00002	
Inside enclosed porch								
Utility Room								

Results

An alternative way of viewing the residential interior field measurement values is provided in Figure 30 where each of the 141 measurements is plotted in order of decreasing value ranging from the overall maximum of 0.08% of the MPE to smaller values. The greatest measured values pertain to approximately 20% of the total number of measurements. After correction for time and spatial averaging, the maximum and average values are equivalent to 0.0014% and 0.000057% of the MPE respectively.

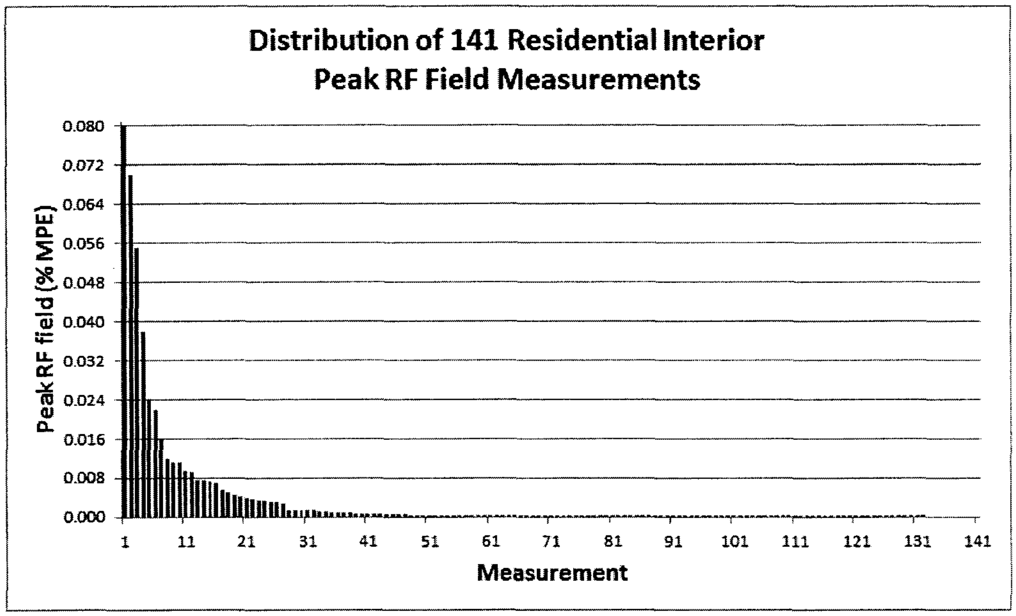

Figure 30. Distribution of 141 residential interior peak RF field measurements in decreasing order.

Assessing Duty Cycles of Smart Meters

The most demanding aspect of characterizing potential exposure of individuals to smart meter RF emissions is determining the duty cycle of operation of the smart meters. This determination is relevant to adjusting measures of instantaneous peak values of RF fields to obtain the actual time-averaged value of field. Time-averaged RF fields, averaged over any 30-minute period, are specified by the FCC for compliance with their exposure regulations. The measured values of RF fields in this report are in terms of instantaneous peak values, relative to a percentage of the MPE. The duty cycle of a smart meter emission is a measure of the ratio of the average power transmitted by the meter to its peak power transmitted over an observation time. For intermittent RF fields that are exactly of the same amplitude, the duty cycle can be defined as the ratio of the "on time" of the field to the total time of observation. As an example, if an intermittent field is on for 1 second once every 10 seconds, then the duty cycle is simply 1/10 or 10%.

Results

In a more general sense, for RF fields that may vary in magnitude during their on-time, duty cycle is defined as the ratio of the overall average of the power, or overall average of percentage of MPE that the signal represents, to the peak value of field, as a percentage of the MPE, during the observation or measurement period. For fields that exhibit the same amplitude each time they exist, these two definitions are the same.

Frequency hopping, spread spectrum smart meters produce only intermittent RF fields (pulses) that last for very short times. The upper range of smart meter signal on-time is in the range of 100 milliseconds (ms) (one tenth of a second) or less with the length of the pulse being related to the information content carried by the transmissions from the smart meter. Previous studies of similar smart meters have indicated typical duty cycles of only a few percent or less [1, 2, 10]. Such small duty cycles result because of the digital nature of the wireless RF LAN, the relatively high speed of data transmission and the small amount of data on electric energy consumption that needs to be transmitted. While each end point meter also serves as a repeater for neighboring meters that need assistance in getting their data to a data collection point, all of this activity only adds up to a relatively small amount which does not require much transmitting time on the part of the smart meter. Taking all of the requirements for the smart meter to actually transmit, including beacon pulses and other network organizational overhead, maximum duty cycles are remarkably small.

How one determines what the duty cycle of a meter is presents considerable challenge. From a measurement perspective, the normal variability in transmission by a smart meter means that measurements performed at any individual meter can take a lot of time and may be fraught with considerable uncertainty. For instance, typical meter activity may vary from moment-to-moment, hour-to-hour and day-to-day. To obtain a good overall picture of transmitting activity of a large number of smart meters could require many days of effort and result in considerable uncertainty from a statistics perspective in the resulting estimate of average activity.

Generally, for exposure assessment purposes, the conservative approach is to determine the maximum duty cycle that may be exhibited by any meter within the network and using this value for adjusting all measured peak values to obtain average levels of potential exposure. It becomes clear that attempting to do this by a direct physical measurement of fields by statistically sampling a large number of smart meters over time can be extremely arduous. Because of this difficulty, past studies have made use of a statistical approach to examining smart meter transmitting activity that has relied on collecting and analyzing data from the utility's smart meter data management software system [1, 2, 10]. If data can be collected from a large portion, or all, of the deployed smart meters in an area on the amount of data transferred wirelessly by the meters, then estimates of the total transmit time can be developed for the associated sampling period. Typical sampling periods have ranged from nominally an hour to as much as a 24 hour period. Thus, average duty cycles can be generated that are applicable to whatever the sampling period was. The strength of this approach is that the statistical estimates can be based on very large numbers of meters and produce results on duty cycles that have high confidence.

An alternative approach was taken for this project in which direct measurements were performed under conditions that would correspond to the greatest meter transmission activity. For both the GMP and BED measurements, each utility arranged for measurements to be made at specific times during which maximum amounts of data would be transmitted. Rather than performing measurements at a large number of meters, focused measurements could be performed on a selected meter or the RF LAN component of a data collection point to obtain estimates of the maximum likely duty cycle of any of the meters in the system. Hence, through a contrived scenario in which the greatest amount of data that would normally ever be transmitted, duty cycles could be directly measured for the Vermont smart meters in this study.

In this project, a feature of the SRM-3006 that is based on its time-analysis mode of operation was used to directly measure duty cycles. In essence, RF field amplitudes, as a percent of the MPE, were monitored over various time periods but with an emphasis on 30 minutes. The SRM-3006 makes many measurements of the peak and average RF field magnitude that occur within small time increments across the long term monitoring period and directly indicates the measured duty cycle. During these measurements, examples of smart meter pulse characteristics were also collected to examine the duration of the pulses.

Measurements of 900 MHz band RF pulse characteristics during the Vermont field work allowed evaluation of smart meter duty cycles. Measurements were conducted on single end point meters as well as at banks of meters. In the GMP territory, measurements were strategically made at a single end point meter during the scheduled time of day when maximum meter activity would occur. A 30-minute measurement in the time domain was made at GMP site 1 beginning at 9:15 A.M. (one of the four periods during the day that meters report energy consumption data) as shown in Figure 31. During this measurement period, the meter is scheduled to transmit load profile data back to its data collection point (Gatekeeper in GMP terminology)[14]. This particular meter was selected specifically for the measurements because of its location within the mesh network to which it was assigned; because of its hierarchy within the network, this meter would be expected to exhibit transmit activity related to the 554 meters that communicate through it (GMP was able to provide network maps that allowed the identification of this meter). Based on examination of the Rutland service territory, this meter represented the best opportunity for finding maximum transmit activity and, hence, would provide a conservative measure of maximum meter activity across the

[14] Load profile data consists of the historical record of all 15-minute interval data since the last reporting period, normally six hours.

network. During the measurement period of 30 minutes, a duty cycle of 0.0355 (3.55%) was determined. In Figure 31, the recorded instantaneous peak value of RF field was retained for use in preparing this graph of signal activity. The sweep time of the instrument is divided into as many as 4000 time-resolution increments depending on the overall sweep time. The instrument measures the overall peak and average value of all pulses occurring within each time increment and represents this result as a vertical bar. Each bar can, visually, only represent signal values associated with each time resolution increment. Hence although the peak and average signal amplitudes are accurately measured for all pulses, the number of pulses that occurred or precisely when they occur can be obscured by the particular time, and graphical, resolution.

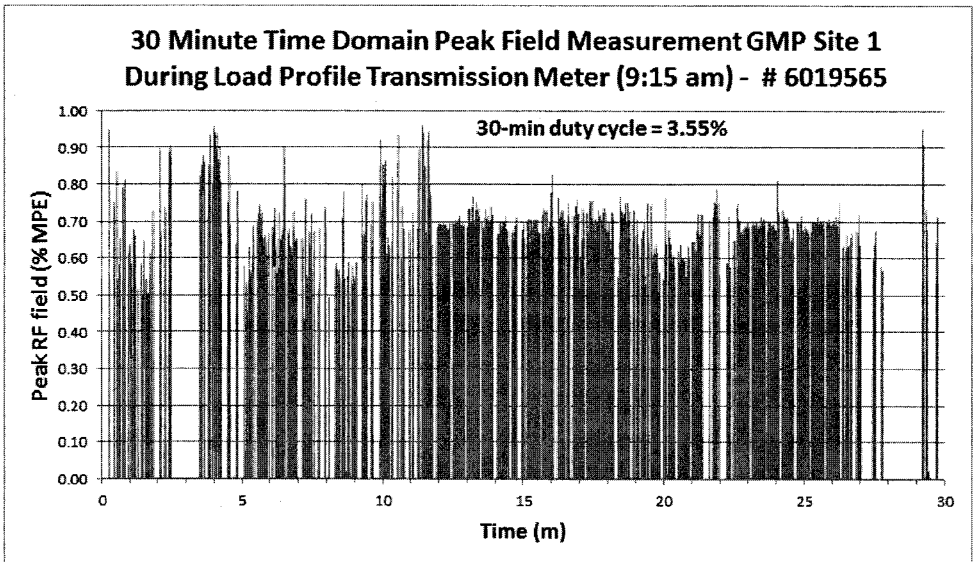

Figure 31. Result of 30-minute time domain measurement of peak RF fields at GMP site 1 during period of maximum expected transmit activity.

The duty cycle result obtained from the measurement shown in Figure 31 represents the greatest 30-minute duty cycle value that was found during any of the project measurements in Vermont.

At the same GMP site (site 1), an additional 30-minute measurement of duty cycle was conducted beginning at 10:15 A.M. This signal sample was captured near the end of the transmission of load profile data but included part of the register reads from meters across the network. Figure 32 illustrates the results of this measurement. The 30-minute duty cycle was measured to be 1.21%.

These values of duty cycle may be interpreted in terms of the how the time-average value of RF field is related to the overall instantaneous peak value of RF field during the 30-minute period in which the measurement was made. From a practical, but conservative perspective, the greatest duty cycle may be used to adjust all reported peak values of RF fields to equivalent 30-minute time-averaged values.

The waveform of a typical pulsed signal response from the GMP meters, after being pinged by the field service unit, is shown in Figure 33. This time domain display shows that the pulse width is very close to 100 ms.

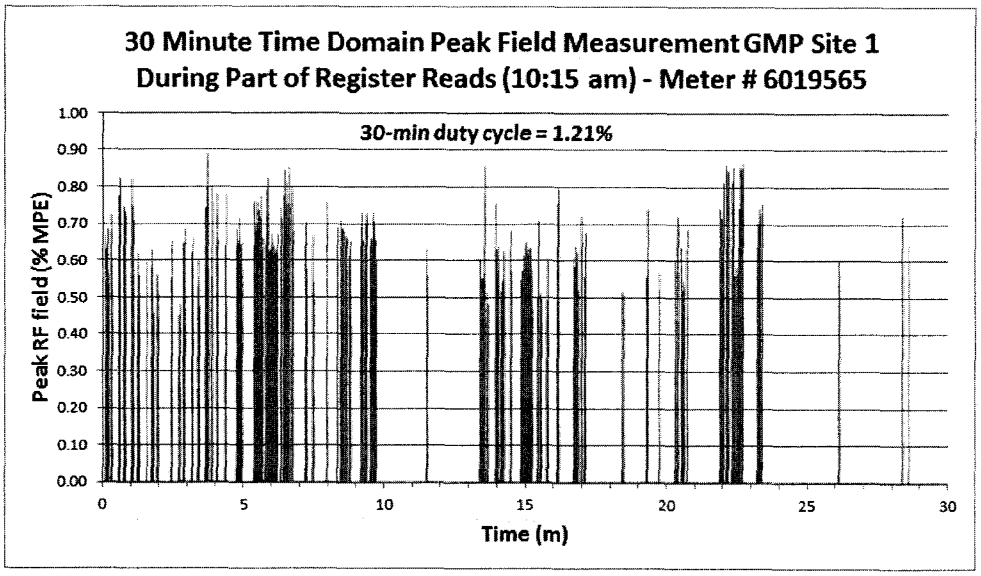

Figure 32. Result of 30-minute time domain measurement of peak RF fields at GMP site 1 during a second period of high expected transmit activity including transmission of register reads from meters.

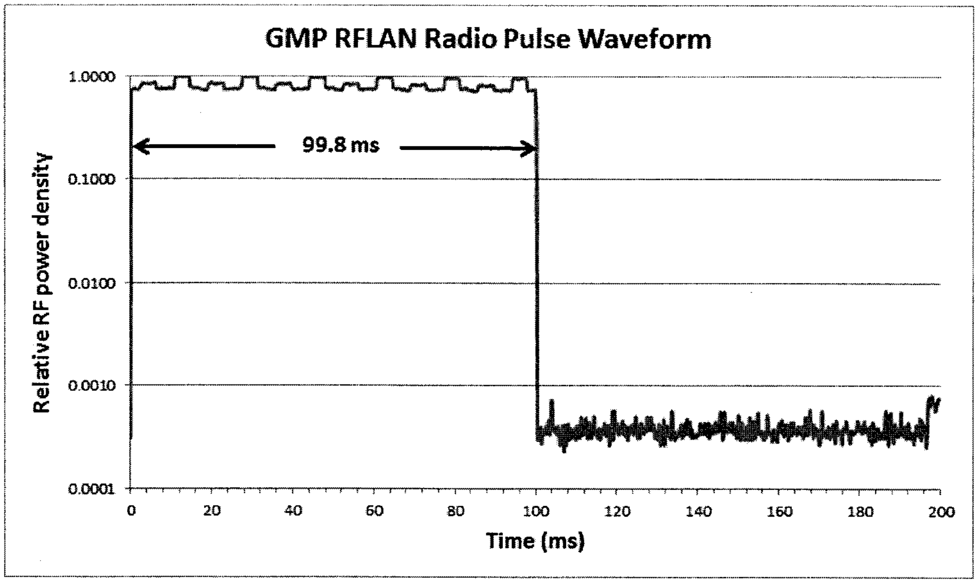

Figure 33. Waveform of GMP end point meter emission when pinged by field service unit.

Additional time-domain measurements were conducted at an end point meter located near the bottom of the network hierarchy (no other end point meters would normally make use of this meter for relaying of data). Three different data transmission scenarios were arranged for these measurements by sending commands from the GMP head end via the wireless network that requested the meter to transmit back the retained 15-minute interval data collected and stored during the past one day, during the past two days and during the entire period (~70 days) since the meter had been initially installed. Figure 34 illustrates these measurement data where the instrumentation was kept active for capturing signal levels as the meter was sequentially instructed to transmit according to the three scenarios. The data collection period existed for approximately 15 minutes. The increased transmit activity is evident, depending on the amount of data being requested from the network head end. In this contrived scenario, the 15 minute duty cycle was found to be 0.141%. The normal duty cycle of this meter would be far less than this value since it would only be transmitting data applicable to the past six hours. Importantly, although the maximum amount of data that could be pulled from this meter was included in the measurement, the process resulted in a very small overall duty cycle when compared to the data acquired at GMP site 1 where historical data from more than 500 meters was involved in the transmission.

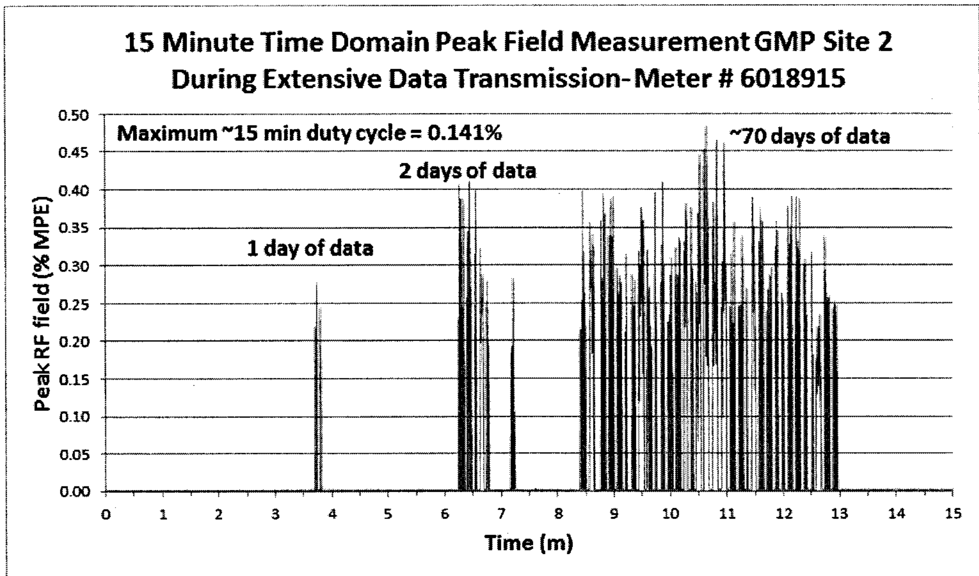

Figure 34. Result of 30-minute time domain measurement of peak RF fields at GMP site 2 during a contrived scenario of three different data transmission requests of the meter (one day's worth of data, two days of data and all of the data stored since the meter had been installed).

Arrangements were made to perform additional measurements of the meter emissions at GMP site 2 during a typical data transmission for comparison with the contrived scenario of maximum data transmission. Figure 35 presents the time domain results for a 30-minute observation. The observed 30-minute duty cycle was found to be 0.022% verifying that the meter transmitting activity is very low under normal operating conditions.

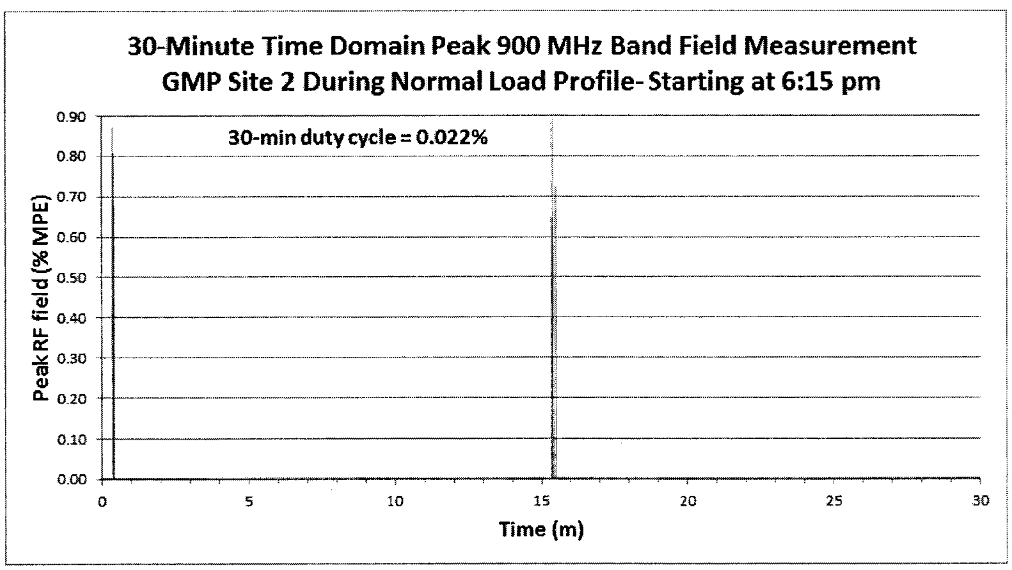

Figure 35. Result of 30-minute time domain measurement of peak 900 MHz band RF fields at GMP site 2 during a normal data transmission request that occurs four times per day.

Results

The 30-minute RF field duty cycle observed at a meter bank of 14 meters (GMP site 3) was measured during the scheduled period for meter transmissions. The SRM-3006 probe/antenna was positioned on a tripod near the center of the bank of meters and signal activity was monitored for 30 minutes. The observed result is shown in Figure 36 for which a 30-minute duty cycle of 0.041% was measured. Although there were 14 meters within this bank, only minimal transmit activity was observed. It is relevant to note that when the request for meters to report interval data is transmitted out to all of the end point meters from the network head end, this does not necessarily mean that the meters within this specific bank of meters will report sequentially in time. While one meter in the bank may report, other meters located physically elsewhere may sequentially report before another one of the meters within the bank becomes active. This likely leads to the relatively sparse amount of signal activity over this period near the bank. Differences among signal peak values are likely related to the different distances between the probe/antenna and various meters within the bank and the transmitting pattern of each meter.

Measurements of meter transmit activity were also performed at a GMP Gatekeeper (site 8). This was accomplished by, first, identifying the cellular WWAN frequency used by the Gatekeeper, using the SRM-3006, in spectrum analysis mode, to observe for the presence of a predominant signal when the probe/antenna was held near the WWAN antenna on the Gatekeeper (a step ladder was used to gain access to

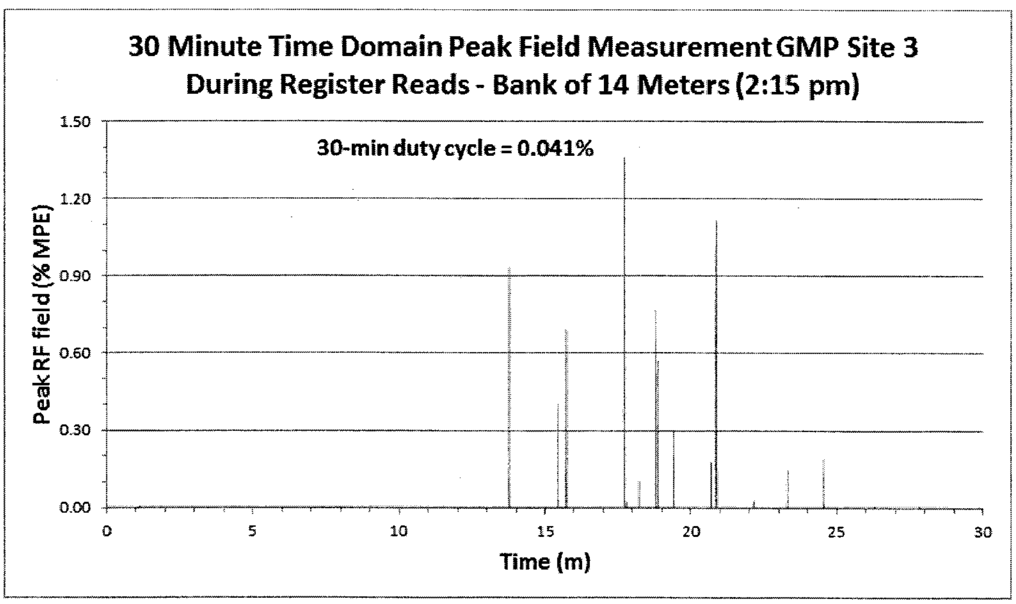

Figure 36. Result of 30-minute time domain measurement of peak RF fields at a bank of 14 meters (GMP site 3) during a normal data transmission period that occurs four times per day.

the elevated Gatekeeper antennas). Once this frequency was identified, approximately 825 MHz, the SRM-3006 was set to time-analysis mode with a center frequency of 825 MHz and a RBW of 5 MHz to capture the time domain waveform of the emitted WWAN signals. This process was accomplished in rapid manner beginning with the expected start of transmission by the Gatekeeper via the WWAN at 10:15 A.M. The subject Gatekeeper at site 8 has 1245 end point meters that report back to it; it is these data that are, then, put on the WWAN back to the GMP data management system. The measurement of duty cycle was performed with the SRM-3006 on a tripod at three feet above ground level. Figure 37 shows the Gatekeeper box mounted on a power pole at GMP site 8 with the measurement instrumentation situated on a tripod.

Figure 38 shows the result of this measurement exercise. Over the 30-minute observation period, a duty cycle of 0.141% was determined. The relatively small duty cycle observed, despite the large amount of data accumulated from all 1245 end point meters, is likely a result of the high data transmission rate associated with the WWAN such that only a very small amount of time is required to convey the large amount of data to the Internet.

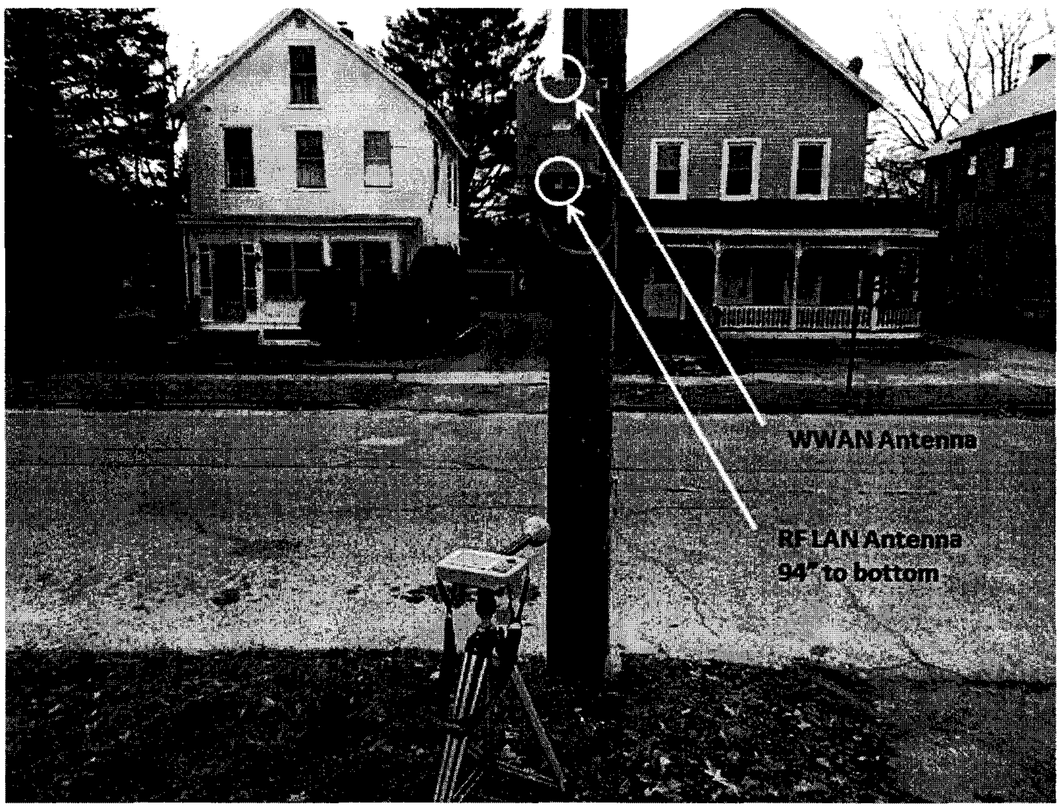

Figure 37. GMP Gatekeeper mounted on a power pole at GMP site 8 with the WWAN antenna on the top and the 900 MHz RF LAN antenna on the bottom.

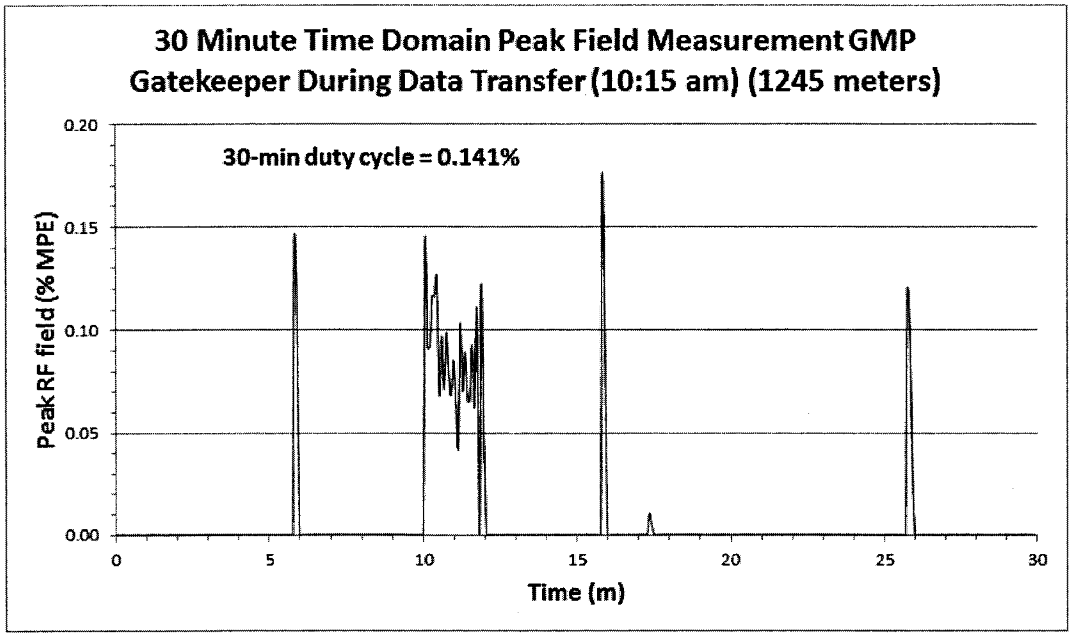

Figure 38. A 30-minute time domain measurement of peak RF fields near the base of a GMP Gatekeeper (site 8) during a scheduled transmission of data accumulated from 1245 end point meters.

In the BED service territory, a different approach was taken to estimate the maximum duty cycle of end point meters. At the time of the project, it was difficult for BED to cause, on command, a prolonged transmission of data from end point meters during which measurements could be made. As an alternative, it was deemed that a suitable substitute could be represented by the transmission activity of the 900 MHz radio within one of the BED Cell Routers during the time that it sends instructions to a mass of end point meters requesting each meter to transmit its data back to the Cell Router. This was assumed to be representative of a high transmission activity from a given end point meter sending stored load profile data. Accordingly, measurements were performed near the base of one of the BED Cell Routers at BED site 1 beginning shortly before a scheduled transmission of instructions via the Cell Router at 8:00 A.M. The measurement began at 7:55 A.M. and continued for a total of 35 minutes, observing the Cell Router 900 MHz emissions. Figure 39 shows the resulting time domain data. The 35 minute duty cycle was measured as 0.041%.

The characteristics of a typical RF pulse observed at one of the BED end point meters is shown in Figure 40. The duration of the pulse is 69.5 ms.

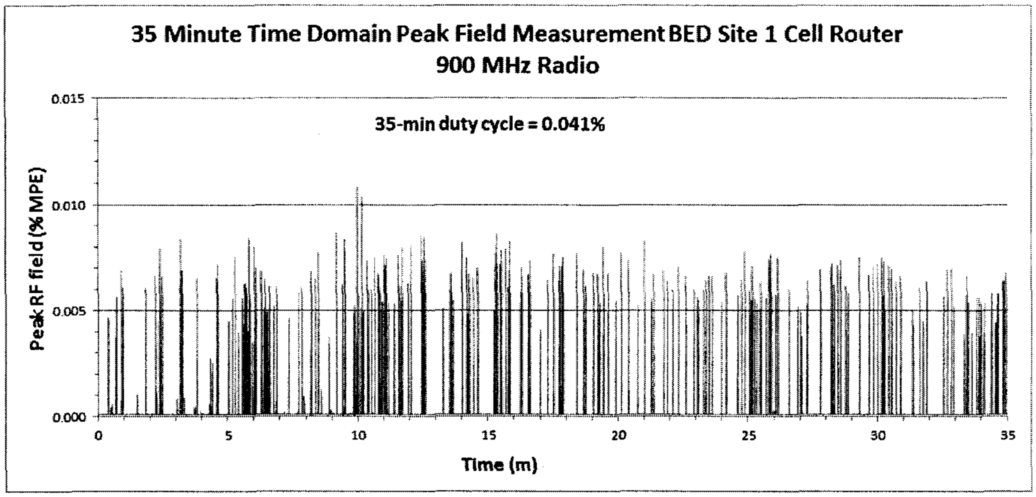

Figure 39. A 35-minute time domain measurement of peak RF fields near the base of a BED Cell Router (BED site 1) during a scheduled transmission of commands to end point meters to respond with data. These data pertain to the 900 MHz band emissions associated with the Cell Router.

Other measurements performed at BED end point meters, while the meter was pinged via the network head end, were used to estimate potential duty cycles during different scenarios consisting of varying amounts of data being transmitted back to a Cell Router. This method was limited in that the software at the head end of the network was difficult to control for specific amounts of data to be transmitted and how often the commands could be repeated. Nonetheless, the greatest observed duty cycle from a single end point meter was measured to be 0.157% over a two minute period.

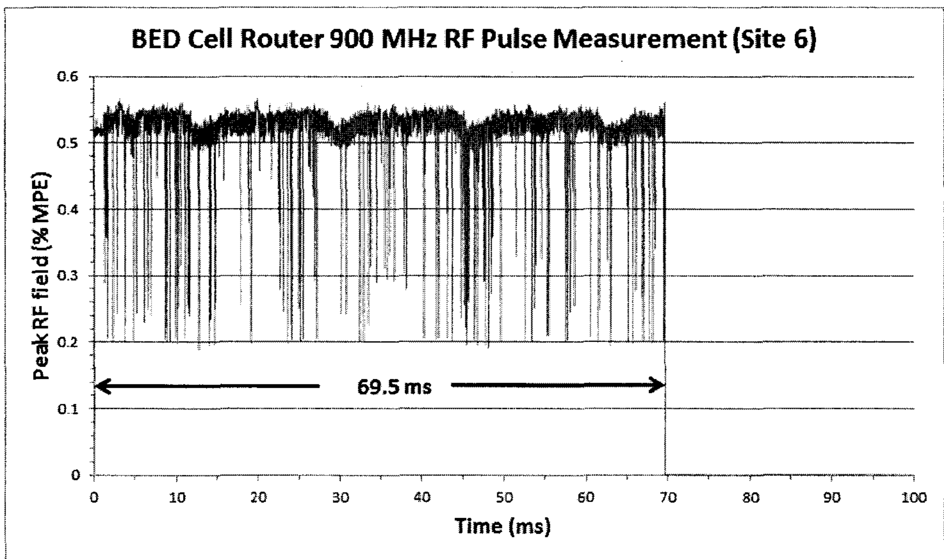

Figure 40. The time domain waveform of a 900 MHz RF pulse emitted by a BED Cell router RF LAN radio (BED site 6). The duration of the pulse was measured to be 69.5 ms.

As a conservative estimate of maximum duty cycle, if one pulse lasting for 69.5 ms were to be emitted once per second (not supported by any of the measurements performed during the project), the corresponding duty cycle, based on a 1 second time analysis of the signal from an end point meter at BED site 8, would be 3.49%. It is not reasonable to assume a continuous stream of such pulses over a 30-minute period but were such to occur, this could represent the maximum possible duty cycle.

HAN radio emissions associated with the GMP end point meters presented considerable challenge because of the rather narrow pulses of RF produced by the HAN transceiver. A time domain waveform of the pulse emitted by the HAN radio is shown in Figure 41. The pulse exists for only 1.79 ms with an even shorter pulse when connected to an IHD.

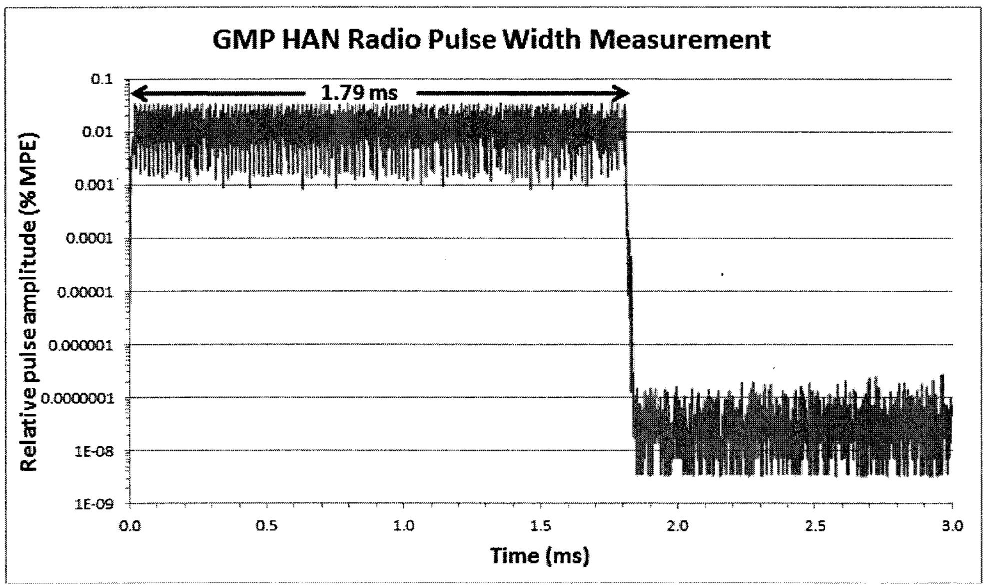

Figure 41. The time domain waveform of an RF pulse emitted by a GMP end point meter HAN radio when there is no IHD to connect with the meter. The duration of the pulse was measured to be 1.79 ms.

Because of the narrow HAN pulse width, the alternative approach of separately measuring the three orthogonal polarization components of the composite RF field was necessary since the settling time of the internal filters within the instrument could not provide a response to the instantaneous peak value of the pulsed field when using the isotropic mode of operation of the instrument. Using the time-analysis mode of the SRM-3006, however, measurements of each field component, corresponding to the X, Y and Z polarizations from the probe/antenna were recorded for each measurement location. Following the measurements, these three component values were summed to obtain the resultant RF field magnitude expressed as a percentage of the MPE.

Initial investigation of the HAN radio emission characteristics revealed that, when the radio is not paired with an IHD, the time profile of emissions consists of nominally four pulses spaced approximately 15 seconds apart plus a burst of four pulses once approximately each minute for a total of some eight pulses, each 1.79 ms wide, every minute. This is illustrated with the time domain measurement shown in Figure 42. This pattern of radio emission activity describes the normal operation of the majority of HAN radios in the GMP deployed meters as observed in this project.

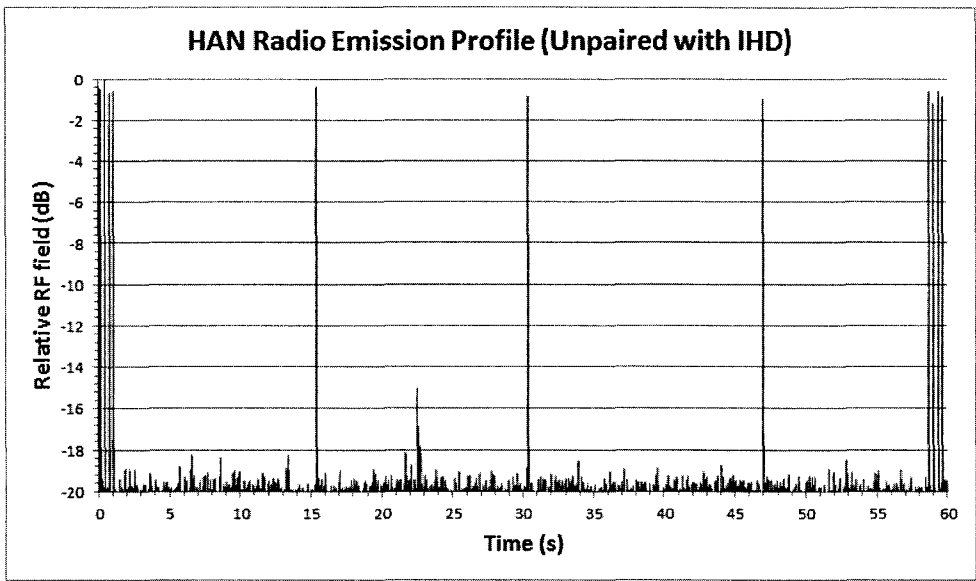

Figure 42. The time domain pattern of RF emissions from a GMP end point meter HAN radio showing a repeating pattern corresponding to nominally eight pulses every minute. The much smaller peak at approximately 23 seconds is unrelated to the operation of the HAN radio.

A different transmit activity exists, however, when a HAN radio becomes linked with an IHD. Interestingly, the pulse emission characteristics of the HAN radio change when it becomes wirelessly connected to an IHD. When connected to an IHD, two things happen; the number of pulses occurring increase and the width of the pulse decreases substantially. This observation is best illustrated in Figures 43 and 44. When the HAN radio is paired with the IHD, the pulse width of the emitted signal is reduced from 1.79 ms to 0.35 ms. However, the IHD signal is approximately the same width as the HAN radio signal when it is not paired with the IHD.

In Figure 44, the amplitude of the IHD signal is substantially greater simply because the IHD was relocated to the top of the smart meter, placing it at the same distance from the instrument probe/antenna as the smart meter and its internal HAN radio.

A 30-minute measurement of the time domain profile of the emissions from the HAN radio obtained at GMP site 2, where the smart meter HAN radio is not paired with an IHD, is shown in Figure 45. The 30-minute duty cycle in this case was measured to be 0.00030%, reflective of the narrow pulses of RF field and relatively long periods between pulses.

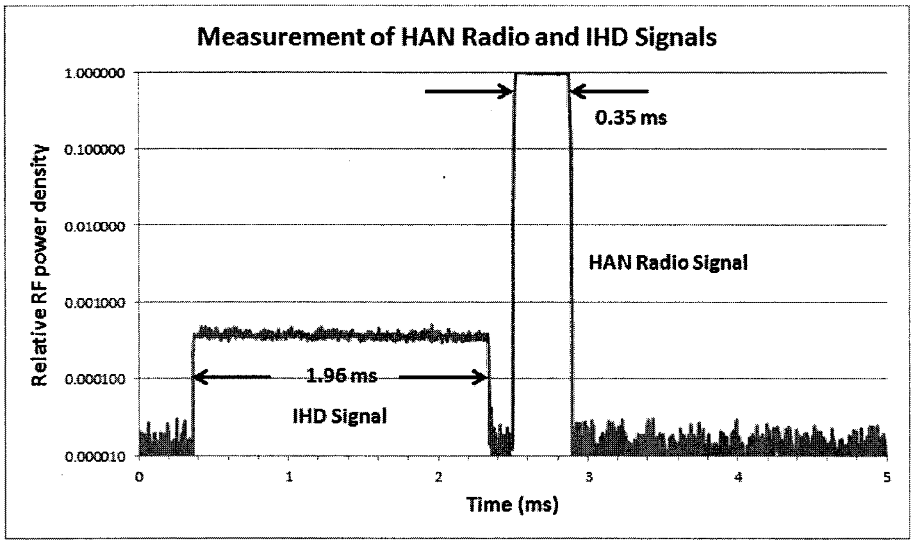

Figure 43. Time domain pattern of RF emissions from the HAN radio and an IHD located approximately 30 feet from the smart meter when the radio is paired with the IHD. Note the narrower pulse width of the HAN radio and the broad signal from the IHD that has the same approximate pulse width of the HAN radio when the HAN radio is not connected to the IHD.

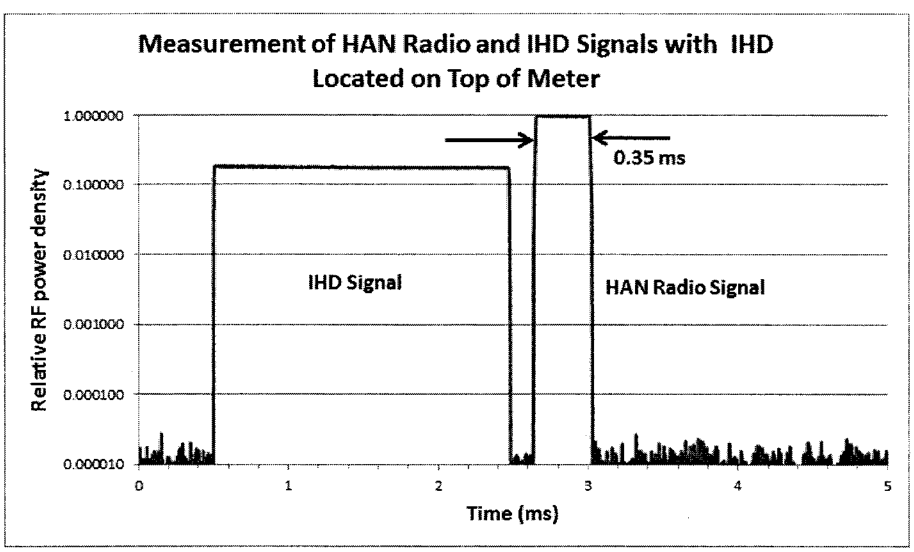

Figure 44. Time domain pattern of RF emissions from the HAN radio and an IHD located on top of the smart meter with the radio paired with the IHD. The amplitude of the IHD signal has increased significantly since it is at the same distance to the measurement probe/antenna.

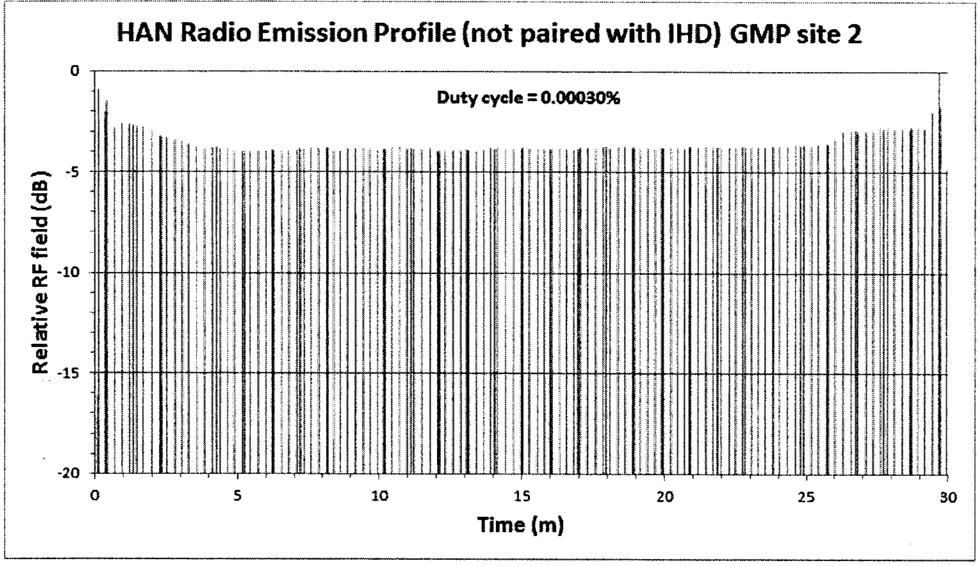

Figure 45. 30-minute time domain pattern of RF emissions from a smart meter HAN radio at GMP site 2 that is not connected with an IHD.

For comparison, another 30-minute measurement performed with the HAN radio that is paired with an accompanying IHD is shown in Figure 46. The result of this measurement was a 30-minute duty cycle of 0.00087%, approximately three times greater than for the unpaired HAN radio.

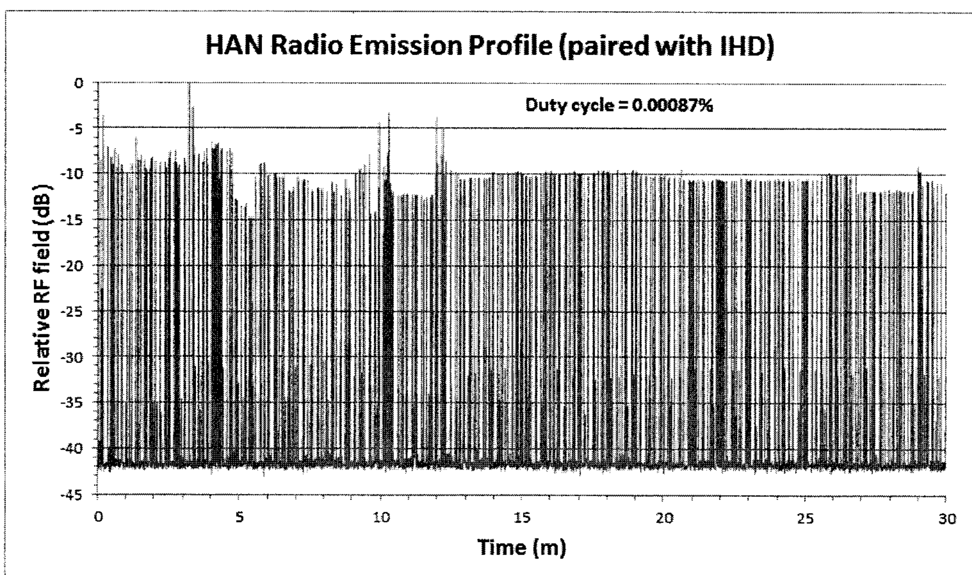

Figure 46. 30-minute time domain pattern of RF emissions from a smart meter HAN radio paired with an IHD.

Further insight to the HAN radio emission characterization is provided in Figure 48 which represents a time domain measurement at a bank of six smart meters (GMP site 13), none of which were paired with an IHD. A long term duty cycle of 0.00034 resulted. In Figure 47, a visual image of varying line density of the vertical bars representing the measured signals is presumably caused by the presence of other HAN radio signals incident on the measurement probe/antenna. At least four different levels of apparent signal strengths are seen. The top level of signal, closest to the 0 dB line, is due to the signal from the smart meter that the probe/antenna was closest to with the other lower level signals being related to emissions of the other smart meters within the bank. Only the closest smart meter will lead to the strongest measured signal; the other meters, due to greater distance between the probe/antenna and meter as well as variations in the emission pattern of the smart meter HAN radios, results in lower measured signal levels.

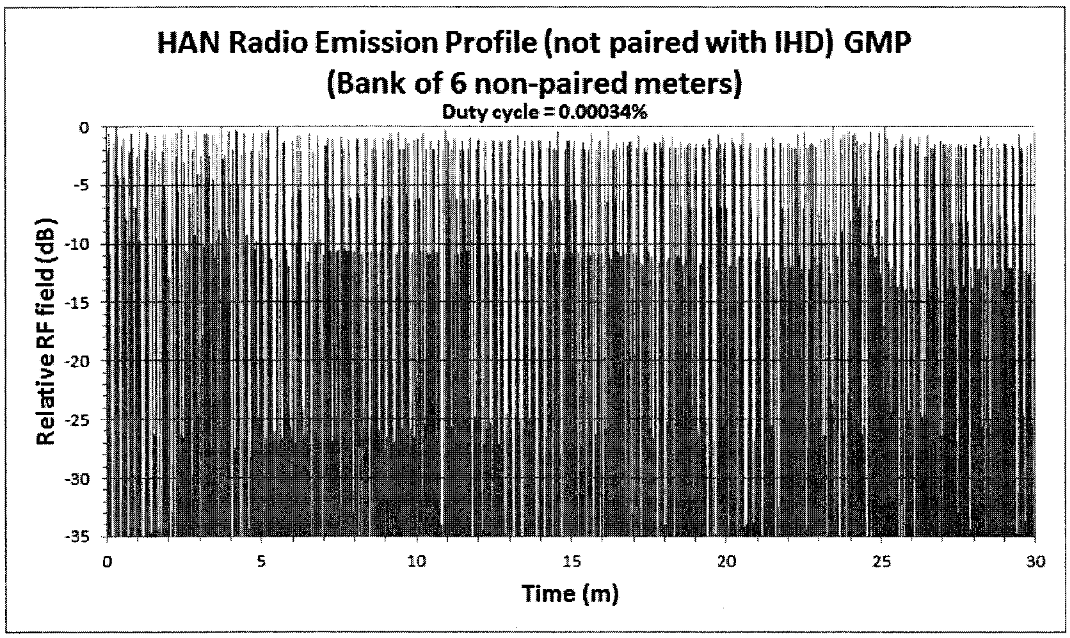

Figure 47. 30-minute time domain pattern of HAN radio emissions from a bank of six meters (GMP site 13) that are not paired with IHDs.

Another 30-minute HAN radio emission profile with the radio paired with an IHD is shown in Figure 48 where the overall duty cycle was found to be 0.00073%.

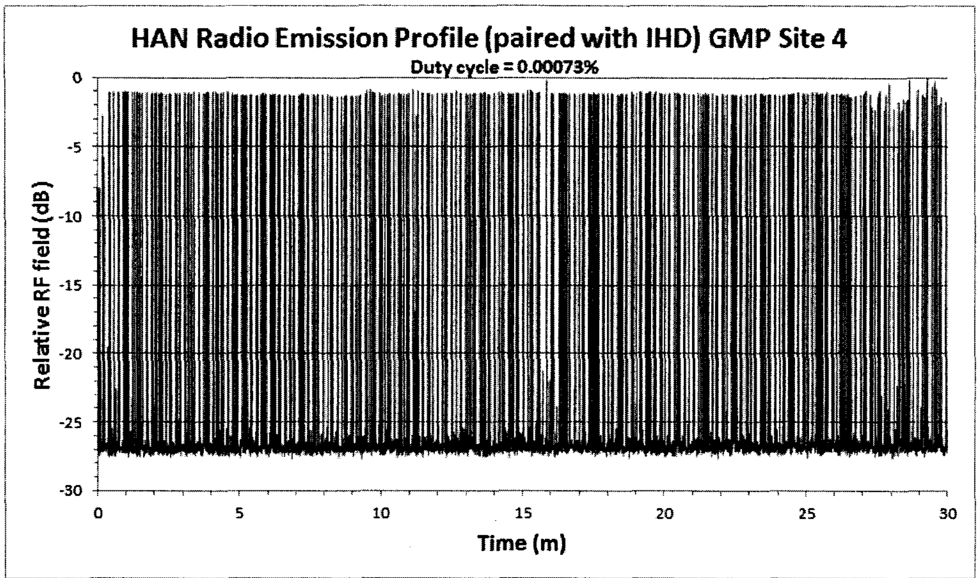

Figure 48. 30-minute HAN radio emission profile at GMP site 4 with radio paired to an IHD.

Table 8 summarizes the duty cycle assessments of the HAN radios obtained under a number of different conditions and at several different sites during this project. These measurements include work done in Vermont at different GMP sites and in Colville. For the measurements in Vermont, the designation Active Meter means that the meter had been activated for use with a specific IHD; an Inactive Meter was not activated for use with an IHD. An additional, third, smart meter was made available for use during the tests in Vermont. During the Colville measurements, two separate GMP smart meters were available designated as SM1 and SM2. SM1 had the HAN radio activated for use with an IHD; SM2 did not.

Table 8. Summary of duty cycle measurements of HAN radios, IHDs and a 2.4 GHz cordless telephone under different conditions and for different measurement durations.

Measurement	Condition	Duration (min)	Duty cycle (%)
1	SM1 on paired with IHD	30	0.087
2	SM1 on with IHD off	30	0.016
3	SM1 and SM2 on, IHD off, observing SM1	30	0.030
4	SM1 and SM2 on, IHD off, observing SM2	30	0.061
5	SM1 and SM2 on, IHD on nearby,	30	0.073

Results

	observing SM2		
6	SM2 on with IHD on, SM1 off	30	0.082
Table 8 continued.			
7	SM1 and SM2 off, IHD on	30	0.106
8	SM2 on and SM1 off, IHD on and close to instrument	30	0.171
9	SM1 on, IHD off	2	0.016
10	Active meter paired with IHD, 2nd active meter paired with separate IHD, 3rd inactive meter on	2	0.062
11	Active meter paired with IHD, second IHD on but not paired with meter, 2nd inactive meter on	2	0.019
12	Active meter paired with IHD, 2nd active meter with IHD off, 3rd inactive meter on	2	0.067
13	2 active meters + 1 inactive meter, all IHDs off	2	0.045
14	2 active meters with paired IHDs both on, 3rd inactive meter on + 2.4 GHz cordless phone on in house	2	0.258
15	2.4 GHz cordless phone	2	1.552
16	Active meter on, non-paired IHD on, 2nd inactive meter on	2	0.024
17	Bank of 6 inactive meters, no IHD	2	0.032
18	Bank of 6 inactive meters, no IHD	30	0.034
19	Inactive meter, no IHD	2	0.003
20	Inactive meter, no IHD	30	0.034
21	Bank of 14 meters, all non-paired, no IHDs	2	0.022
22	Active paired meter with IHD on, measurement near IHD in home	2	0.071
23	Active paired meter with IHD in home, measurement near meter	2	0.087
24	Active paired meter with IHD in home, measurement near meter	30	0.029

Low Frequency Field Measurements

Results

As part of this project, low frequency electric and magnetic fields were measured at one foot in front of the test meters provided by both GMP and BED. The Narda EHP-50D instrument, capable of isotropic measurements (that provide measures of the resultant field magnitude by forming the result of three orthogonal polarization values), was used to acquire background spectra of electric (E) and magnetic (B) fields prior to powering on the smart meters and, subsequently, acquisition of the E and B field spectra upon powering up the meters. Measurements were performed over the frequency spans of nominally 0 to 1 kHz, 0 to 10 kHz and 0 to 100 kHz to provide a broad perspective on any fields within these frequency ranges. Associated with the spectral measurements of field vs. frequency, a value of the wideband RMS value of the field is also provided.[15] Table 9 lists the wideband values of electric field strength and magnetic flux density for each of the three frequency ranges mentioned and for both the GMP Elster meter and the BED Itron meter. No electrical loads were placed on either meter during the measurements that would introduce potentially strong 60 Hz magnetic field components simply due to the current flow through the meter.

Table 9. Summary of low frequency measurement values of wideband (RMS) electric field strength (V/m) and magnetic field flux density (μT) at 1 foot in front of meter.

		Electric field (V/m)		Magnetic flux density (μT)	
	Frequency	Background	Smart Meter	Background	Smart Meter
GMP	0-1 kHz	0.4682	35.126	0.0235	0.0909
GMP	0-10 kHz	0.1775	12.105	0.0107	0.045
GMP	0-100 kHz	0.1866	0.2091	0.019	0.0196
BED	0-1 kHz	0.4682	35.808	0.0235	0.5708
BED	0-10 kHz	0.1775	12.375	0.0107	0.2987
BED	0-100 kHz	0.1866	0.2227	0.019	0.0296

Spectrum analysis results showing the distribution of frequency components across the 0 to 1 kHz, 0 to 10 kHz and 0 to 100 kHz spans are shown in Figures 49, 50 and 51 for electric fields and in Figures 52, 53 and 54 for magnetic fields.

[15] Wideband values of electric and magnetic fields do not include the first 1.2% of any components in the frequency spectrum. This is to eliminate the local oscillator zero feed through associated with any spectrum analyzer at zero frequency.

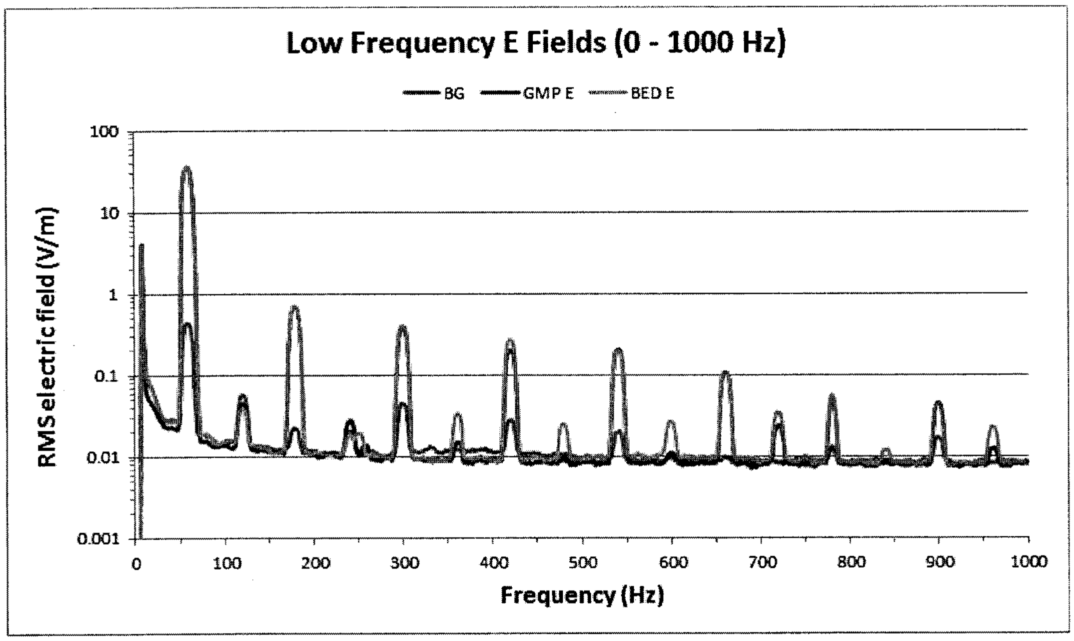

Figure 49. Low frequency electric (E) fields measured in the range of 0 to 1,000 Hz (1 kHz) for the GMP Elster meter, the BED Itron meter and background.

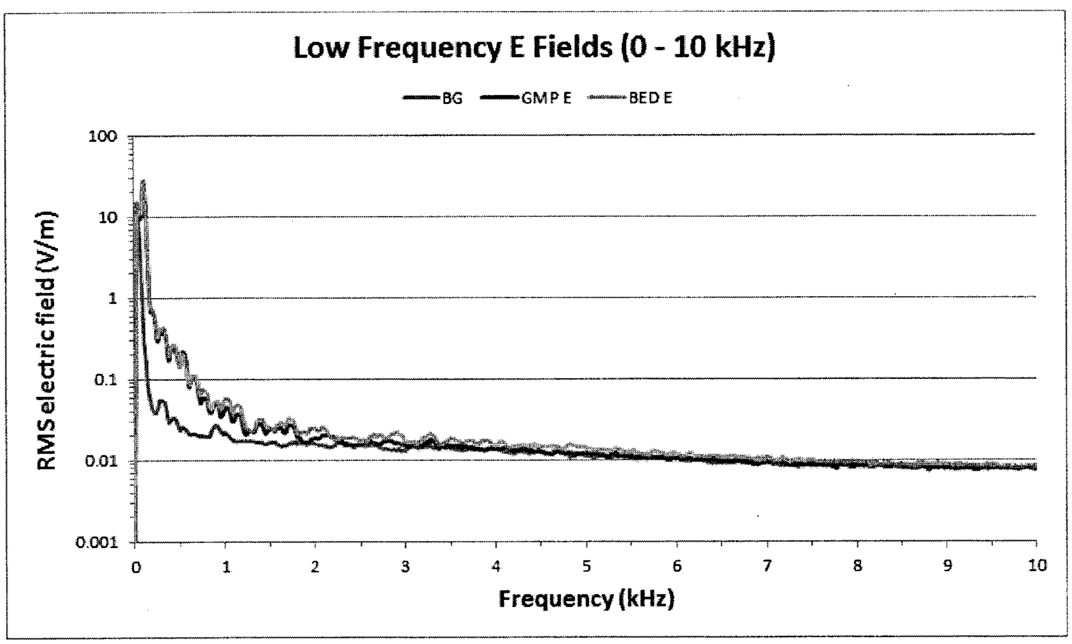

Figure 50. Low frequency electric (E) fields measured in the range of 0 to 10 kHz for the GMP Elster meter, the BED Itron meter and background.

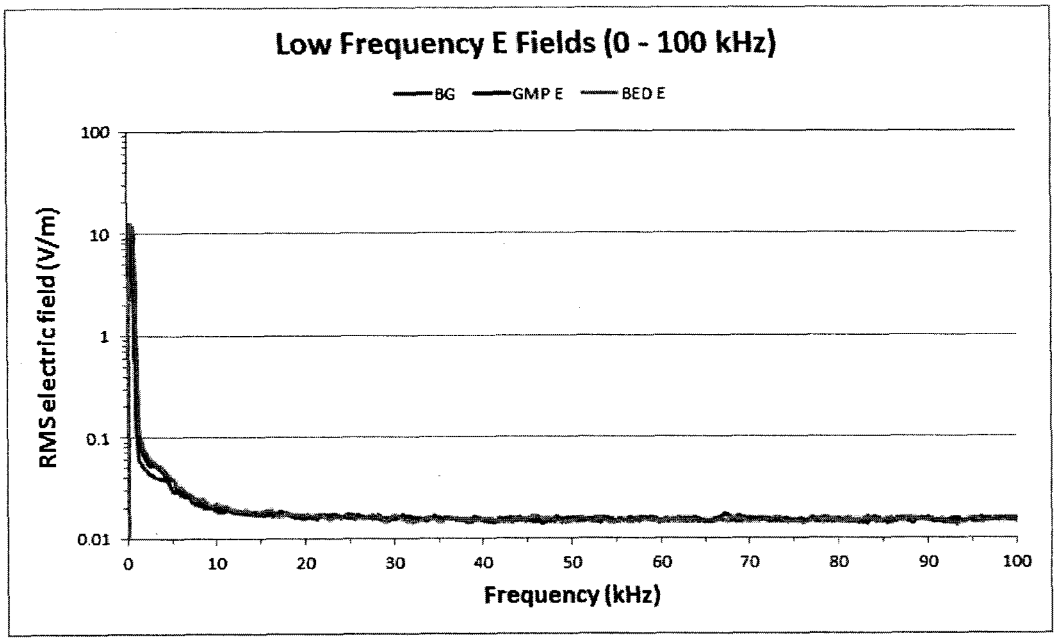

Figure 51. Low frequency electric (E) fields measured in the range of 0 to 100 kHz for the GMP Elster meter, the BED Itron meter and background.

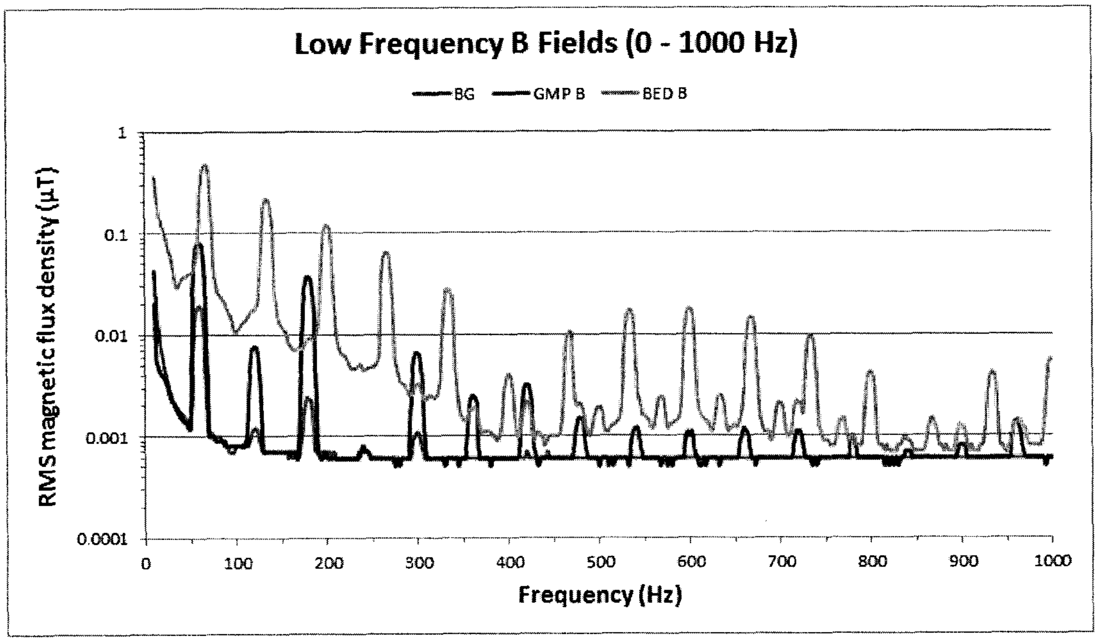

Figure 52. Low frequency magnetic flux density (B) measured in the range of 0 to 1,000 Hz (1 kHz) for the GMP Elster meter, the BED Itron meter and background.

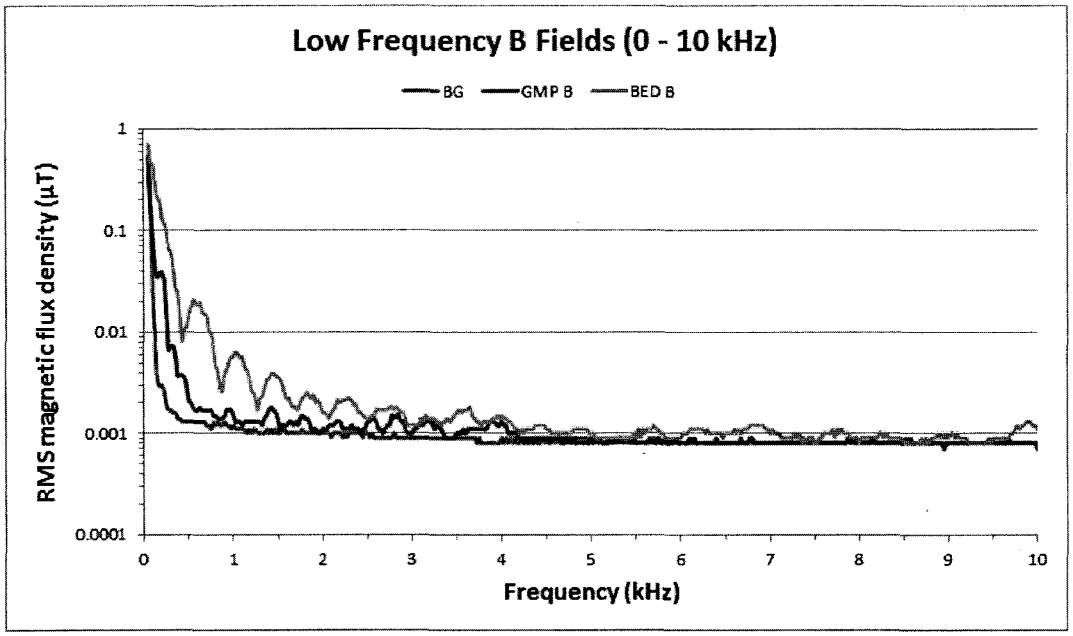

Figure 53. Low frequency magnetic flux density (B) measured in the range of 0 to 10 kHz for the GMP Elster meter, the BED Itron meter and background.

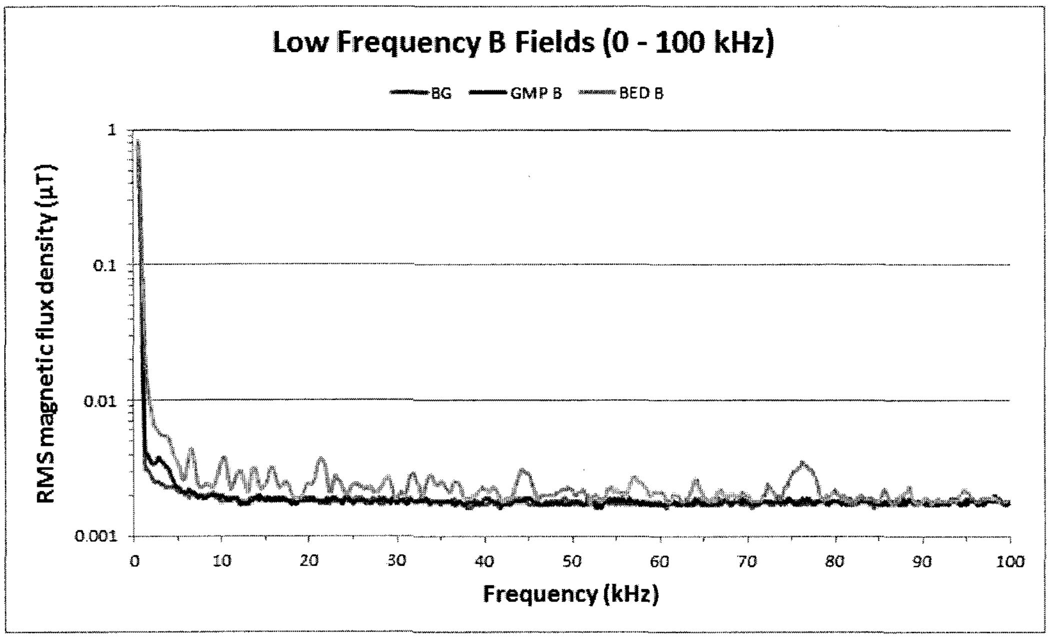

Figure 54. Low frequency magnetic flux density (B) measured in the range of 0 to 100 kHz for the GMP Elster meter, the BED Itron meter and background.

Results

Measurements of Other Sources

While smart meter RF emissions were the principal focus of this study, during the field work in Vermont, measurements of RF fields associated with a number of other types of RF sources were also conducted. Mostly, these measurements were opportunistic in nature when the opportunity presented itself. In some cases, these measurements took place during the measurement of interior smart meter RF fields in homes included in the study. In others, referred to as "environmental" measurements, the measurements were performed outdoors in different parts of the state ranging from Rutland in the South, Montpelier in the East, Saint Albans in the North and Burlington to the West. A total of 14 environmental sites were included at which measurements of radio and television (TV) broadcast signals and wireless base station signals were performed as well as a few instances of investigation of unique signal characteristics. These data help provide a foundation for interpreting the relative magnitude of potential public exposure to RF fields produced by smart meter emissions.

Multiple HAN Radio Emissions

When measuring in the 2.4 GHz license free band, signal activity from a number of different kinds of devices can often be observed. This is illustrated by Figure 55 which shows a measured spectrum at GMP site 3. The measurement was performed inside the building on which the meter bank was mounted, inside a closet located directly behind the meter bank. In this case, the emissions of four HAN radios are clearly seen as well as a wireless router (see labels in figure). Given more time, other HAN radio emissions would be expected to be seen but it is important to note that the display of RF fields is the result of a "maximum hold" mode of the measuring instrument in which the greatest measured RF field at any given instant in time and on any given frequency is retained and displayed. This means that while there may be numerous peaks shown in a spectrum, each associated with a particular HAN radio transmission, they may have not occurred simultaneously nor operate continuously.

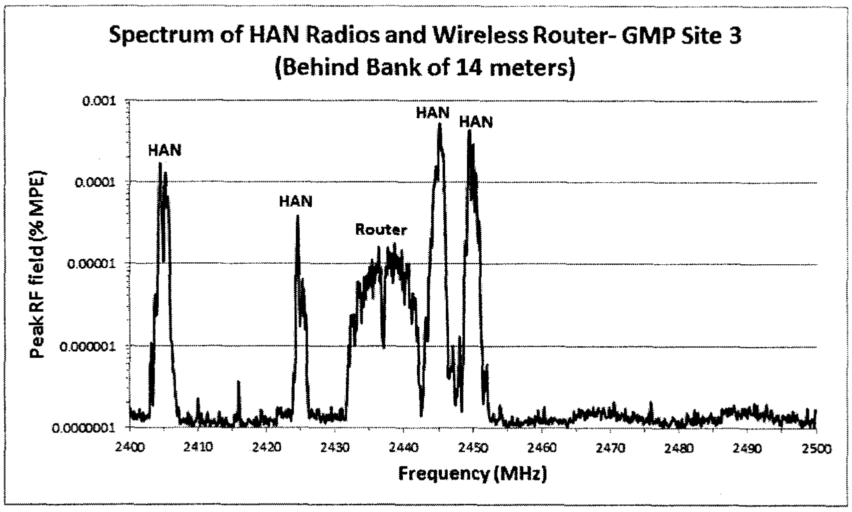

Figure 55. A measured spectrum of RF fields at GMP site 3, behind a bank of 14 smart meters, showing the presence of four HAN radio emissions and a wireless router.

2.4 GHz Cordless Phone

At one of the measurement locations, measurements were made of the RF spectrum produced by a 2.4 GHz cordless telephone (not a cell phone). The phone handset was removed from its base station cradle and turned on as if to make a call while the measurement probe/antenna was placed at one foot from the handset. A broadband display of RF fields resulted from 2400 MHz to approximately 2483 MHz that appeared to be relatively continuous in nature. Figure 56 illustrates this measurement.

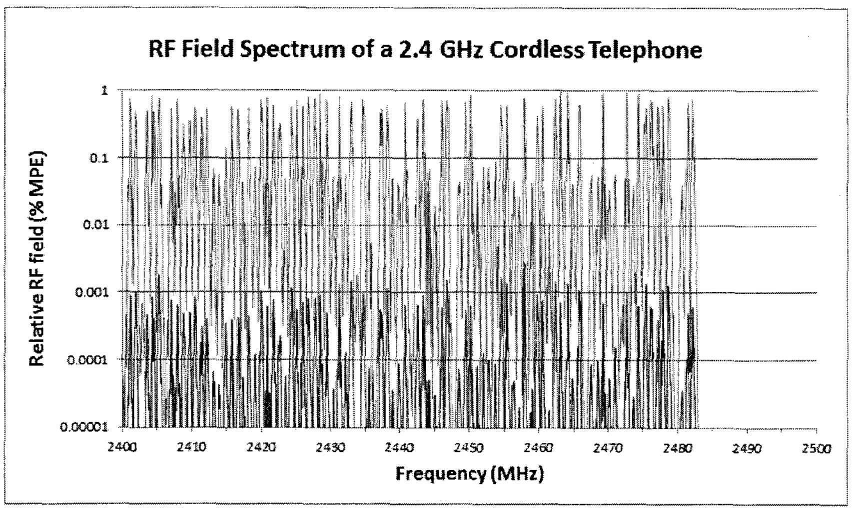

Figure 56. The relative RF field spectrum (blue is peak, red is average) of a 2.4 GHz cordless telephone at one foot from the hand set after it was turned on. RF emissions occur across a large portion of the 2.4 GHz license free band.

Following the spectrum measurement shown in Figure 56, a time domain measurement was made of the cordless phone signal over a two minute period. This measurement resulted in a two-minute duty cycle of 1.6% as shown in Figure 57.

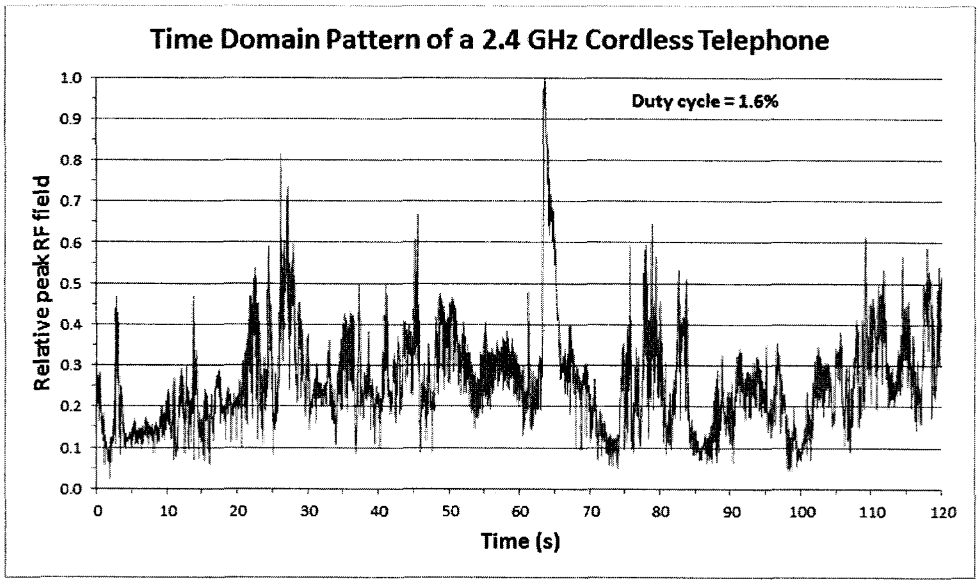

Figure 57. A measured time domain profile of the 2.4 GHz cordless telephone over a two minute (120 second) period. The duty cycle of this two minute capture of signal was 1.6%.

FAA Long Range Air Traffic Control Radar

While in the Saint Albans vicinity, the RF fields associated with an FAA long range air traffic control radar were monitored. While the instantaneous peak RF fields were relatively weak, the measurement illustrates another source in the environment that can result in long term exposure to pulsed fields. The radar site near Saint Albans was taken over full time by the FAA from the Air Force in approximately 1979. Since that time, it has been modified and includes what is now referred to by the FAA as a Common Air Route Surveillance Radar (CARSR). Such radars commonly use an antenna rotation rate, for scanning the skies, of five revolutions per minute (RPM), peak transmitter powers of over a megawatt (1,000,000 watts) and pulse repetition rates of, typically several hundred pulses per second.

Figure 58 shows the results of a one minute time domain profile of the detected signal (at 1,269.5 MHz) from the radar which was located approximately 1.5 miles southeast of the measurement site (environmental site 7). The illumination of the measurement probe/antenna of the SRM-3006 on each revolution of the radar antenna is evident with the maximum peak signals (fields) spaced in time by exactly 12 seconds (equivalent to five RPM). The arrival of main beam emissions of the radar antenna are indicated by the small blue arrows above the peaks. Each time the radar antenna rotates the signal level significantly increases and repeats its pattern. Other peaks in Figure 58 represent side lobes of the radar antenna. Their relative amplitude, compared with that of the main beam, are also influenced by the terrain between the radar and the measurement location which introduces reflections of the radar signal and alters what would be expected purely on the basis of the antenna transmitting pattern in free space.

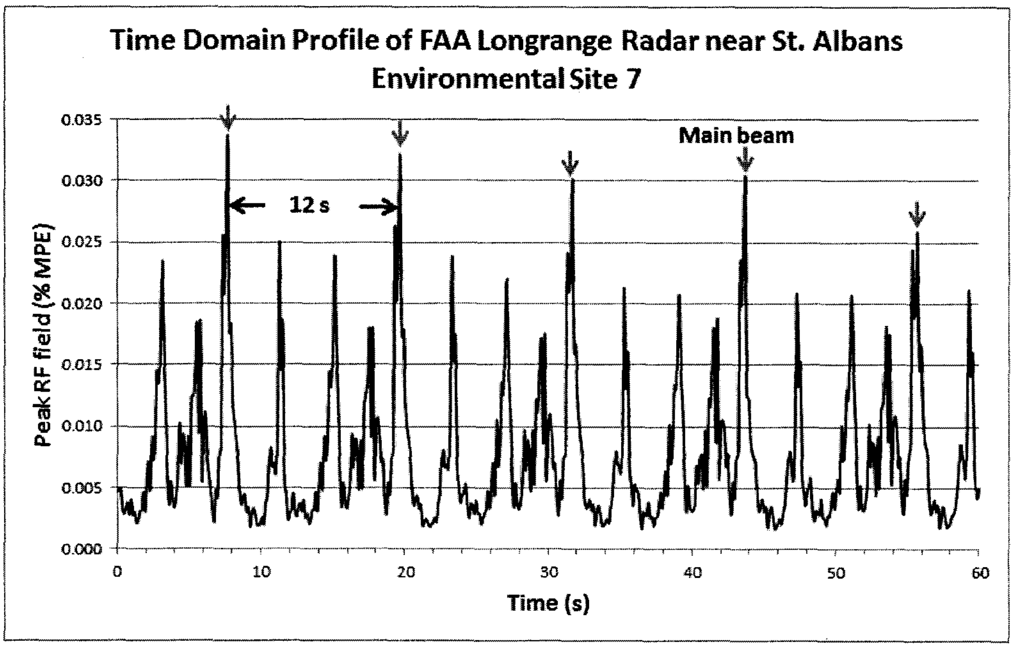

Figure 58. Time domain profile of an FAA long range radar located on a hill east of Saint Albans, VT at environmental site 7. The 5 RPM rotation rate of the antenna is apparent with the major peaks spaced exactly 12 seconds apart. The smaller peaks are side lobes of the antenna and the result of reflections within the environment of the measurement.

<u>Microwave Ovens</u>

Generally, the strongest source of RF fields within a home is a microwave oven. Most microwave ovens operate with powers ranging from about 750 watts to 1200 watts at 2.45 GHz. Despite careful design which reduces any leakage from microwave ovens to very low levels, some microwave energy is always present near ovens while they operate. RF field measurements were performed at distances from one foot to five feet in front of two microwave ovens during the course of this project, one at GMP site 4 and the other at BED site 2. The results of these measurements are plotted in Figure 59 in terms of the <u>average</u> RF field. A cup of water was place in each oven during while it operated and the field measurements were taken. The differences in measured values of RF fields for the two ovens can be related to the possible different operating power levels of the ovens, their physical condition at the time of measurements (which can affect leakage) and the nature of the local measurement environment near the ovens. The data show that average RF fields corresponding to 1% of the exposure limit for the public were observed at distances of as much as three feet from the oven.

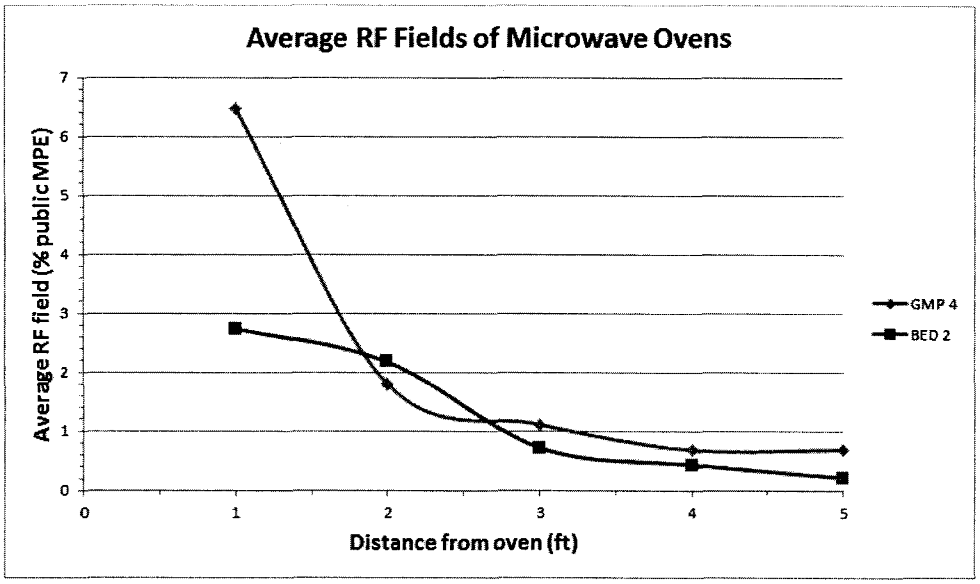

Figure 59. Measured average RF fields produced by two microwave ovens between one and five feet from the oven as it operates.

<u>Wireless Routers</u>

The widespread use of the Internet in many homes has led to the presence of wireless routers for distribution of Internet connectivity with portable/mobile devices. The spectral characteristic common to wireless routers is shown in Figure 60 for a router at GMP site 5 at a distance of one foot from the router. At the time of the measurement, the data transfer rate through the router was unknown. The unique spectrum signature presented by wireless routers permitted easy identification of their presence during measurements of the smart meter HAN radios that operate in the same band. In some cases, as many as four, and possibly more, routers were seen in the background of the measured spectra of the HAN radios, this more commonly associated with homes that had been converted to multiple apartments.

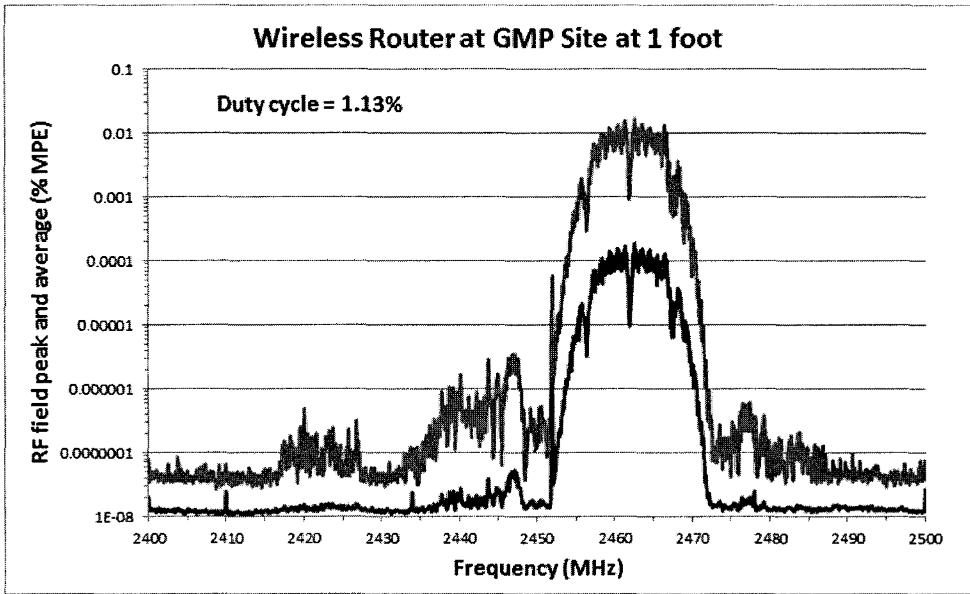

Figure 60. Unique spectral characteristic of 2.4 GHz wireless router at GMP site 5. Based on an integration of the peak (blue) and average (red) RF fields, the apparent duty cycle of the router was determined to be 1.13%.

The continuous peak RF field as a function of distance from six different routers measured during the study is shown in Figure 61. The RF fields are seen to vary widely and this is undoubtedly due to the highly variable nature of the local environments of the routers. In some cases, the routers were in the clear while in other cases they were buried behind monitors, books or other items. Also, the measurements were made with the router in its normal orientation at the site; this may have not been optimum in terms of the antenna for producing the maximum field at the location of the measurement probe/antenna for any particular router. In most cases, accessing the near vicinity of the router was difficult. Since the router is a source of intermittent RF emissions while it is powered on, the intermittent peak RF fields reported are constantly present.

Additional measurements of router duty cycles were performed in Colville. A LinkSys model WRT-54G router was configured for operation on WiFi channel 1, centered at 2412 MHz, and used to wirelessly transfer large amounts of data in different formats to a distant laptop computer. With the router in idle mode, the observed duty cycle was approximately 0.53%, this being roughly comparable with the router simply transmitting its narrow and periodic beacon signals (for network management) at a 10 Hz rate. When transferring binary data, the duty cycle rose to 2.4%. The greatest duty cycles were observed when transferring video files in either .avi or .mov formats when a maximum value of 6.5% could be measured. The issue of duty cycles of routers used with Wi-Fi technology as it is related to the transmission of data has been addressed previously [11].

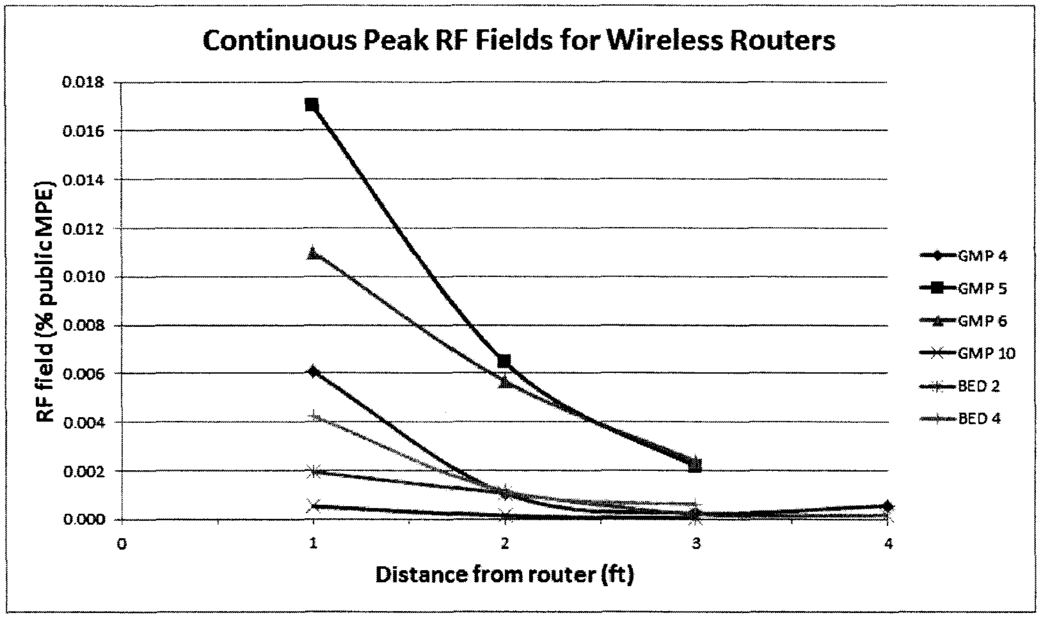

Figure 61. Spatial variation of peak RF fields continuously emitted by six wireless routers measured during this project.

Cell Phones

During the work in Colville, measurements were made of RF fields produced by a mobile phone (Samsung model Blackjack II). Although mobile phones are evaluated for RF exposure on the basis of specific absorption rate (SAR), these measurements were performed to provide perspective on potential exposure to cell phones and smart meters. The measurements consisted of supporting the mobile phone on a dielectric stand at a height of five feet above a concrete floor. The phone was placed into a continuous call during the measurements and the SRM-3006 was used to measure the field starting at floor level and in one foot intervals up to six feet above the floor. At each measurement point, the phone was rotated in three axes while the instrument was in maximum hold mode. This allowed the instrument to record the greatest RF field that might be associated with any particular orientation of the phone and its internal antenna. The phone operated at approximately 840 MHz during the measurements though it was a dual band phone and could operate in the 1.9 GHz band as well.

Figure 62 illustrates the measured peak values of RF field produced by the cell phone at the seven different heights. The greatest field is correlated with the fixed height of the phone. Similar to a smart meter, the spatially averaged value of RF field is substantially less than the spatial peak value near the mounting height of the phone.

The ratio of the spatially averaged field to the spatial peak field is 0.308; i.e., the spatially averaged field is 30.8% of the spatial peak value, similar to the finding for a smart meter. Relative to the MPE, the spatially averaged RF field, derived from instantaneous peak values of field, corresponded to 3.28% of the MPE.

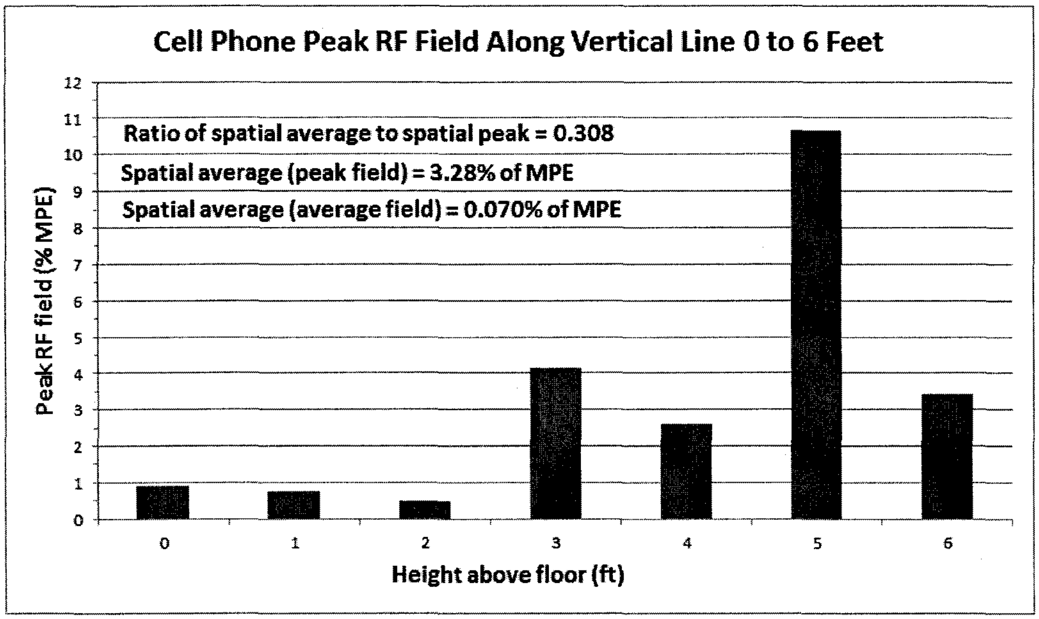

Figure 62. Peak RF fields along a six foot vertical line spaced laterally one foot from an active 840 MHz cell phone fixed at five feet above a concrete floor. The spatially averaged field in terms of time-averaged RF fields (0.070% of MPE) is obtained by multiplying the peak value by the duty cycle (see text below).

To calibrate this peak value of field to an average value, a measurement was made of the duty cycle of a one minute transmission (phone call during which the phone was modulated by a moderate level of speech) by observing the time domain profile of the phone's emission and simultaneously recording the peak and average values of field.[16] Figure 63 illustrates this measured time domain pattern of fields from the phone. It is noted that there are abrupt changes in the signal level (RF field) at different times during the test call suggesting that the phone is dynamically changing its power in response to the mobile phone base station to which it is connected at the time. The observed duty cycle of the phone during this transmission was 2.13% meaning that the average RF field, as a percent of MPE, is nominally 2% of the instantaneous peak field. Using this value of duty cycle, the spatial average of fields shown in Figure 62 (above), when converted to a time-averaged value of field (relative to the MPE) is 0.070% of the MPE.

[16] Note that with a continuously present RF field, this is straightforward with the SRM-3006. However, for intermittent emissions, such as smart meters, this is more difficult to do via a single measurement.

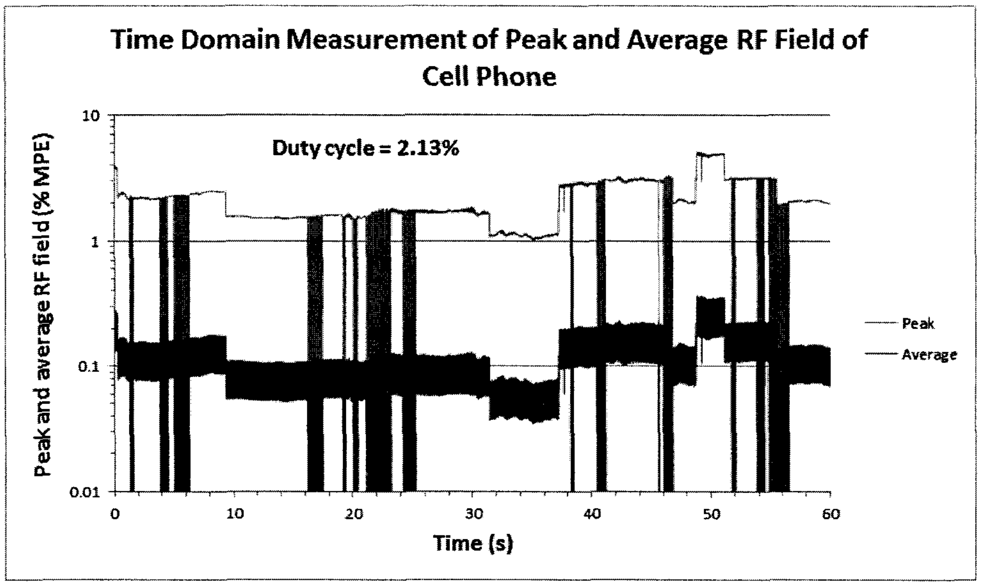

Figure 63. A measurement of the duty cycle of a cell phone across a 60 second phone call during which the phone was modulated with a moderate level of speech. The measured duty cycle was 2.13%.

Broadcast Signals

Broadcast stations provide essentially continuous RF fields of low magnitude that are widespread throughout the environment. The SRM-3006 instrumentation allowed for relatively convenient measurement of both broadcast signals, consisting of signals in the low and high very high frequency (VHF) television (TV) bands, the FM radio broadcast band, and the ultrahigh frequency (UHF) TV band, and the signals produced by wireless communications base stations used for mobile phones. Measurements of these frequency bands were made at 11 of the 14 general environmental sites for this study. Table 10 lists each band measured, the frequency range of the band and the resolution bandwidth (RBW) of the SRM-3006 used for the measurement[17].

[17] Resolution bandwidth is a measure of the ability of the instrument to distinguish signals that are close in frequency. It is similar to the selectivity of a radio receiver.

Results

Table 10. List of frequency bands measured at environmental sites in Vermont, their frequency ranges and the resolution bandwidth (RBW) of the SRM-3006 instrument used during the band measurement.		
Band	Frequency range (MHz)	RBW of SRM-3006 (kHz)
Low VHF TV	54 to 88	100
FM radio	88 to 108	30
High VHF TV	176 to 216	100
UHF TV	470 to 700	500
Cell	700 to 2500	1000

The measurement process consisted of supporting the SRM-3006 probe/antenna above the roof of a vehicle with the use of a 24 inch piece of PVC pipe and a cable allowing connection to the SRM basic unit. Representative spectra of detected average RF fields for the different bands from several different locations within the state are shown in Figures 64, 65, 66, 67, and 68 for the low VHF TV, high VHF TV, FM radio, UHF TV and what will be designated in this report as the cell band (for cellular telephone base stations) respectively.

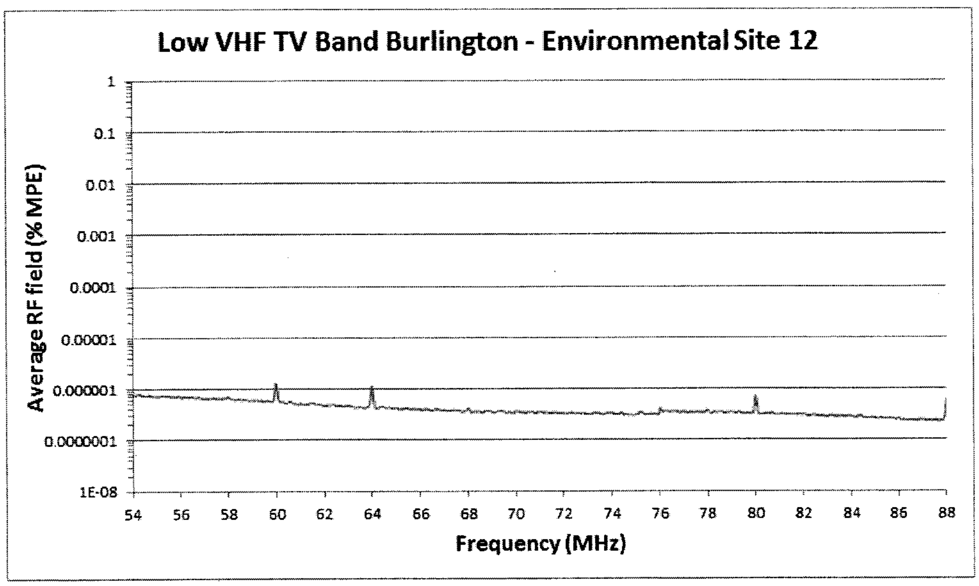

Figure 64. Spectrum measurement of average RF field (% MPE) across the low VHF TV broadcast band at environmental site 12 in Burlington.

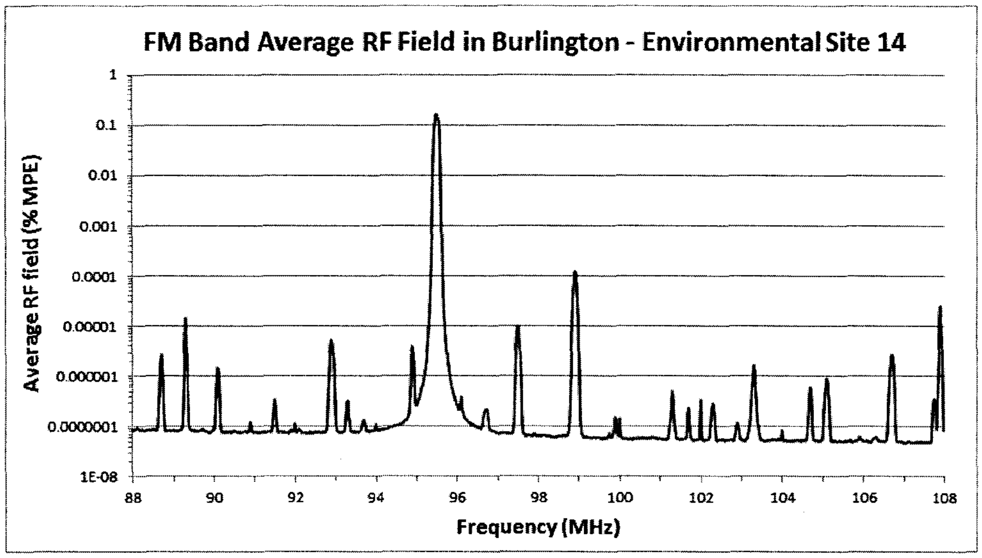

Figure 65. Spectrum measurement of average RF field (% MPE) across the FM radio broadcast band at environmental site 14 in Burlington.

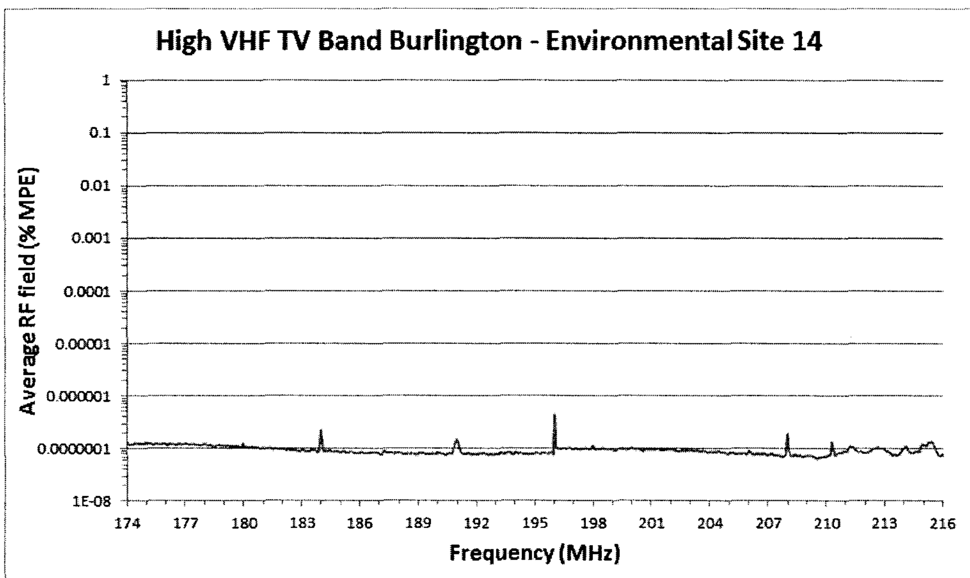

Figure 66. Spectrum measurement of average RF field (% MPE) across the high VHF TV broadcast band at environmental site 14 in Burlington.

The general lack of broadcast signals in the low and high VHF TV broadcast bands is the current result of the transitioning from analog to digital (high definition) TV wherein virtually all VHF TV stations were provided UHF TV spectrum for establishing a digital presence. This has resulted in these two bands becoming relatively vacated.

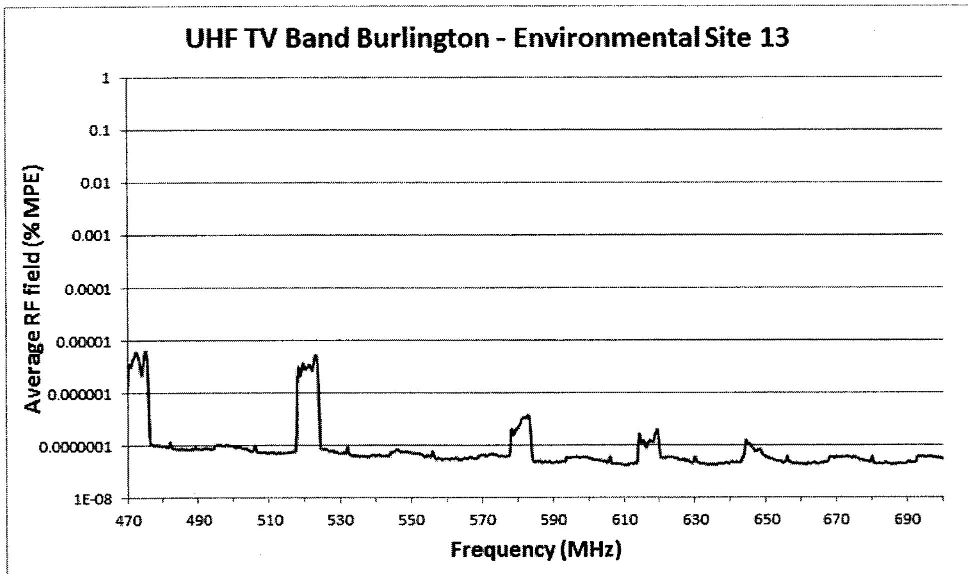

Figure 67. Spectrum measurement of average RF field (% MPE) across the UHF TV broadcast band at environmental site 13 in Burlington.

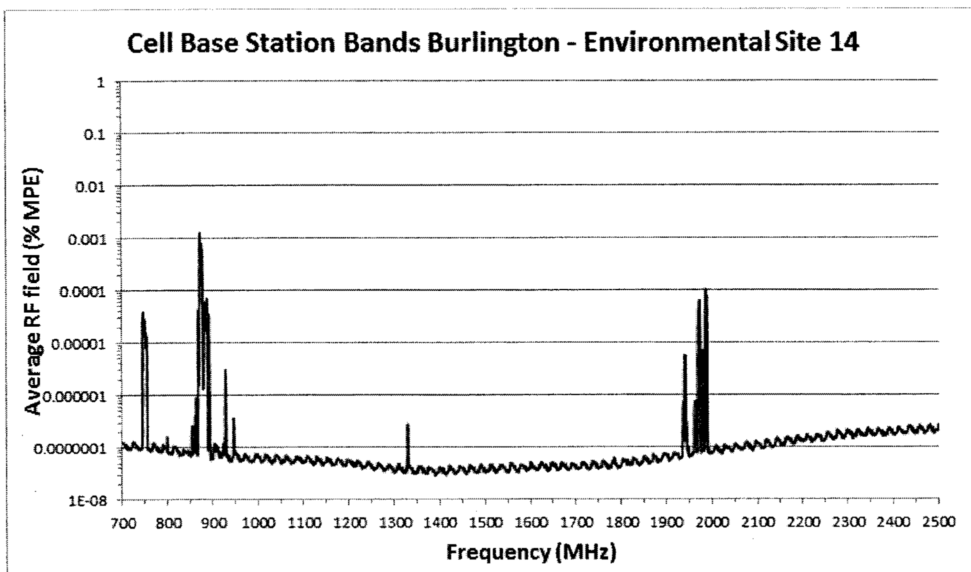

Figure 68. Spectrum measurement of average RF field (% MPE) across the wireless communication (cellular telephone) base station bands at environmental site 14 in Burlington.

For each spectrum measured, the data were retained and subsequently post processed to obtain the aggregate value of RF field from all signals detected within each band. This process consists of integrating the amplitude data obtained from the analyzer using a method specified by Narda. By independently integrating the spectra, using a computer based software tool developed for this purpose, a threshold could be specified for each band measurement such that only the amplitudes of legitimate signals were included in the integration. In this fashion, there was no impact caused by integration of the noise level of the instrument which can drive integrated results to erroneously high values. The specifics of the integration process are provided in Appendix F.

After integration of each measured spectrum of signals, the overall effective value of RF fields in that band were assessed as a percentage of the FCC MPE and tabulated in Table 11. These results are graphically illustrated in Figure 69. Generally, signals measured in the FM radio broadcast band were strongest and resulted in the greatest integrated values of RF field. In some instances, the fields in the cell (wireless) band were greater. This is consistent with a dated but only nationwide study of broadcast RF fields in metropolitan areas of the US [12].

Table 11. Summary of environmental RF field measurements (non-smart meter) in Vermont. Average RF fields are expressed in terms of a percentage of the MPE for public exposure and were obtained through an integration process described in the text to obtain a composite RF field value that also accounted for the noise floor of the instrument.

	Lo VHF	FM	Hi VHF	UHF	Cell
1	4.99E-06	0.003315	1.71E-05	0.000119	0.000237
2	1.36E-05	9.09E-05	3.69E-05	4.49E-06	0.009462
3	2.53E-05	0.000252	1.5E-05	8.14E-06	0.000171
4	3.22E-05	8.21E-05	5.33E-06	8.4E-06	0.000122
5	7.98E-06	1.58E-05	2.95E-07	2.76E-06	0.001135
6	1.92E-05	7.99E-05	2.57E-07	9.84E-06	4.89E-05
10	3.23E-05	0.006532	3.41E-07	9.43E-06	0.00393
11	3.14E-05	0.00925	6.09E-07	3.14E-05	2.55E-05
12	3.81E-05	0.000657	3.36E-07	5.52E-05	4.97E-05
13	3.66E-05	0.003438	3.24E-07	9.56E-05	0.001101
14	2.93E-05	0.616876	3.27E-07	8.71E-05	0.004996

These data support the conclusion that the total composite field of all of these bands range from 0.00016% to 0.62% of the MPE, depending on the site.

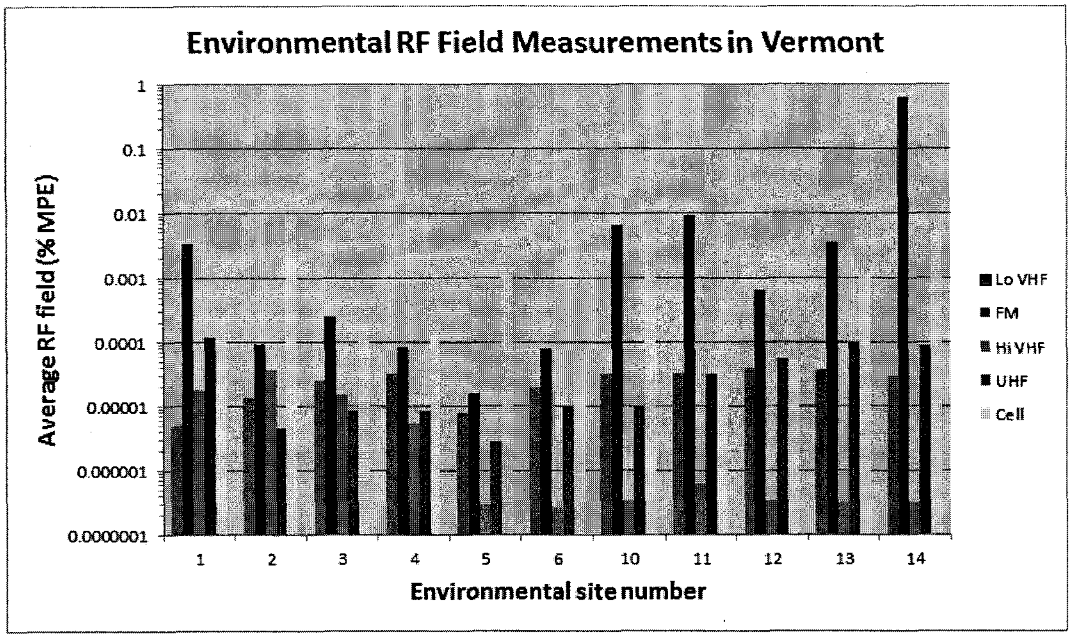

Figure 69. Graphical display of the integrated RF fields across five different frequency bands allocated to broadcast TV and FM radio as well as mobile phone base stations (wireless or cell band).

Water Meter Signals

In the GMP service territory measurements, at some sites, RF signals were observed that were not associated with the smart meters. This was evident since the Elster smart meters only operated in the lower half of the license free 900 MHz band. When extraneous signals appeared, it was very evident. Upon investigation, these signals that occur above 915 MHz but within the 900 MHz band were identified as being emitted by a small box, sometimes located on the home in the same area as the smart meters. This box was found to be related to a wireless remote water meter reading system present on some homes[18]. Figure 70 shows a measurement result in Rutland where the RF signals above 915 MHz are seen. Because the output power of the water meter transmitter is lower than that of the Elster RF LAN radio, it is unlikely that the strength of the water meter generated signals that could exist, from time to time, below 915 MHz would exceed that of the smart meters measured.

[18] Neptune Technology Group, frequency hopping spread spectrum transmitter used for remote water meter reading that operates on 50 hopping frequencies between 910 MHz and 920 MHz with 22 dBm (158 mW) of power and transmits once approximately every 14 seconds.

Results

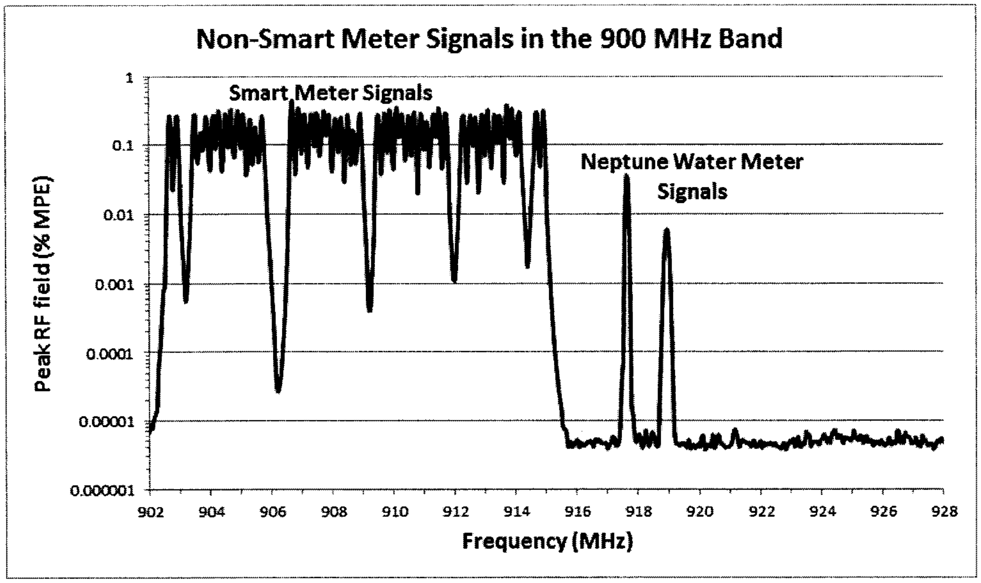

Figure 70. Spectrum measurement result at GMP site 4 where RF fields above the frequency range in which the Elster meter operates are apparent. The signals are intermittent and appear approximately once every 14 seconds.

Discussion

Discussion

This study is, generally, about low power radio transmitters and how they relate to potential exposure of individuals. An extensive set of measurements of two different types of smart meters being deployed within Vermont determined that the RF emissions produced by them are, in fact, low in value when compared to the applicable limits on human exposure promulgated by the FCC. The field characterization process consisted of measurement of the instantaneous peak value of RF fields during the emitted brief pulses from the meters and a direct determination of the meter duty cycles. Hence, both the peak values of RF fields as well as their time-averaged values, needed for direct comparison to the FCC MPE values, were determined. The frequency hopping, spread spectrum radios in the GMP and BED smart meters operate with very small duty cycles which means that time averaged values of RF fields to which someone may be exposed will be even lower than the measured peak values by typically two orders of magnitude.

The duty cycle may be thought of as a factor that is used to adjust the peak measured value of field to a time averaged value; it is a measure of the ratio of average to peak RF fields, or exposures. An averaging time specified in the FCC RF exposure rules of 30 minutes is required for proper exposure assessment and considerable effort was used to acquire direct measurements of 30-minute duty cycles in the project.

The matter of assessing compliance with the FCC rules can be simplified by the process illustrated in Figure71.

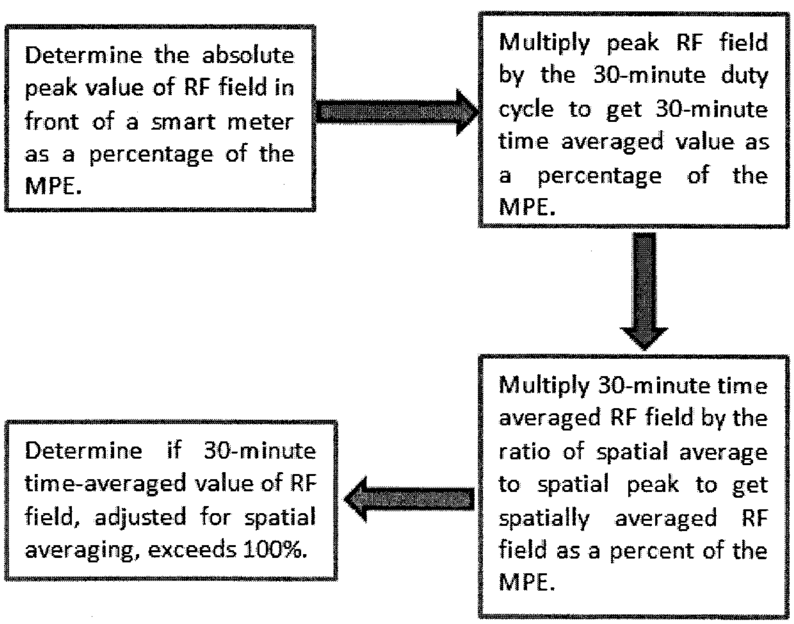

Figure 71. Illustration of steps for assessing compliance with the FCC rules on human exposure used for this study.

Discussion

A simple but conservative observation from all of the presented RF LAN (900 MHz band) data is that the greatest measured <u>peak</u> RF field obtained at a distance of one foot from any smart meter in the GMP service territory corresponded to 3.9% of the MPE and 2.5% of the MPE in the BED service territory. Other measurements resulted in lower values, sometimes considerably lower. In the GMP meter measurements, the maximum duty cycle found under a condition representing the greatest possible amount of data transmission during the measurement, was 3.55% (Figure 31). For the BED area measurements, a maximum duty cycle of 3.49% was deduced on the basis of pulse width measurements and a presumption of such pulses repeating at a rate of once per second. Using these duty cycle values, the 30-minute time averaged RF fields would be <u>0.14%</u> of the MPE for GMP meters and <u>0.087%</u> of the MPE for BED meters, both at a distance of one foot directly in front of the meters.

As a strict interpretation of the FCC exposure rules, these time-averaged values are to be adjusted to correspond to spatial averages over the body. Using the values of the ratio of spatial average to spatial peak RF fields over a six foot tall person obtained from direct measurements (0.489 for GMP meters and 0.363 for BED 900 MHz band meters), the overall estimated RF exposure to the RF LAN smart meter emissions at one foot would be <u>0.068%</u> of the MPE for the GMP meters and <u>0.032%</u> of the MPE for BED meters.

Associated with the operation of the GMP meters are emissions of the HAN radio that operates in the 2.4 GHz band. A similar exercise with the maximum measured RF field at one foot from the meter, the maximum estimated duty cycle and the spatial variation of field in front of the meter yields a local peak value of field of 0.55% of the MPE, a 30-minute time averaged field equivalent to 0.0014% of the MPE (using a duty cycle of 0.258%) and a resulting, six-foot spatially averaged field equal to <u>0.00049%</u> of the MPE (spatial ratio of 0.349). The exceptionally low duty cycle for the HAN radios is related to the very narrow pulses that they emit and the relatively large amount of time between pulses.

Hence, using the most conservative results from the measurements performed in this study, a potential maximum exposure of individuals to the RF fields associated with the currently deployed smart meters in the GMP and BED service territories is small when compared to the limits set by the FCC. To provide an alternative perspective on how the anticipated exposure near the smart meters compares to the hazard upon which the present exposure limits are based, it is relevant to know that the FCC limits include a safety factor of 50 fold below the presumed threshold of hazard. In other words, the exposure limit is not set at the boundary of potentially hazardous effects. When the above estimated RF field exposures are considered in this light, this means that the most conservative estimates of potential exposure range between approximately 74,000 and 156,000 times less than the hazard threshold.

Discussion

Using manufacturer's specified values for the peak output powers of the RF LAN transceivers and antenna gains (tabulated in Table 1), the peak RF field power density at one foot from the respective smart meters can be calculated with the following expression.

$$S = \frac{EIRP}{4\pi R^2} \qquad \text{Eq. 1}$$

Where
S is the power density (milliwatts per square centimeter, mW/cm^2)
EIRP is the effective isotropic radiated power (milliwatts)
R is the radial distance from the smart meter (cm)

For the GMP Elster meter, at one foot, the peak power density is calculated to be 0.059 mW/cm^2 and for the BED Itron meter, a value of 0.045 mW/cm^2 is obtained. These values can then be expressed as a percentage of the MPE by dividing by the MPE (nominally 0.61 mW/cm^2 at 915 MHz) and multiplying by 100. This leads to calculated peak RF fields at one foot for the GMP and BED meters of 9.6% and 7.4% of the MPE respectively. These values are greater than the maximum peak values measured in this study, an often typical result of modeling calculations for RF fields when compared to actual measurements. In fact, in the FCC certification report provided by Elster to the FCC in which measured RF fields at a distance of 3 meters are provided, the measured values proved to be approximately 4.5 times less than what the theoretical calculation would suggest.

RF fields found behind the smart meters are considerably lower than those values at the same distance but directly in front of the meters. In this work, rearward directed RF fields were found to range between 6 and 8% of the forward value. This generally has a significant influence on the strength of the RF fields that are found inside homes that have smart meters. Indeed, the interior measurements of RF fields for both the RF LAN and HAN radios of the GMP meters and the RF LAN radios of the BED meters prove this. The greatest value of RF field anywhere within a residence was 0.08% of the MPE with an average value of 0.0033% of the MPE, these values before adjustment for duty cycle or spatial averaging. Arguments that reflections will significantly increase ambient values of smart meter fields are not borne out during measurements. Certainly, reflections can, and will, influence the actual value of field measured at any given point in space. This is partly why the plots of RF field vs. distance in front of the meters do not follow a strict inverse square law. But, based on the extensive measurement data taken inside homes, including areas immediately behind the meters, extraordinary fields were not found.

Discussion

If the maximum and mean interior RF fields, found in homes, are adjusted for duty cycle using the largest duty cycle found in this study, they become equivalent to 0.0028% and 0.00012% of the MPE respectively. When further spatially averaged, these values become 0.0014% and 0.000058% of the MPE respectively.

The task of making smart meter RF field measurements is made more complex because of the non-uniform pattern of emissions from the meters. This is illustrated in Figure 72 where a detailed set of measurements were performed in Colville on both of the test meters provided by GMP and BED. This figure shows the spatial dependence of the measured RF field in relation to the center of the face of the GMP Elster and BED Itron meters. It clearly shows how slight differences in the exact location of the measurement probe/antenna can influence the result and this certainly is a factor in some of the spread of data in measurements taken during this study. The difference between the two meters is related to the location within the meter housing where the radios are installed. All distances are from the surface of the meter face to the center of the SRM probe/antenna.

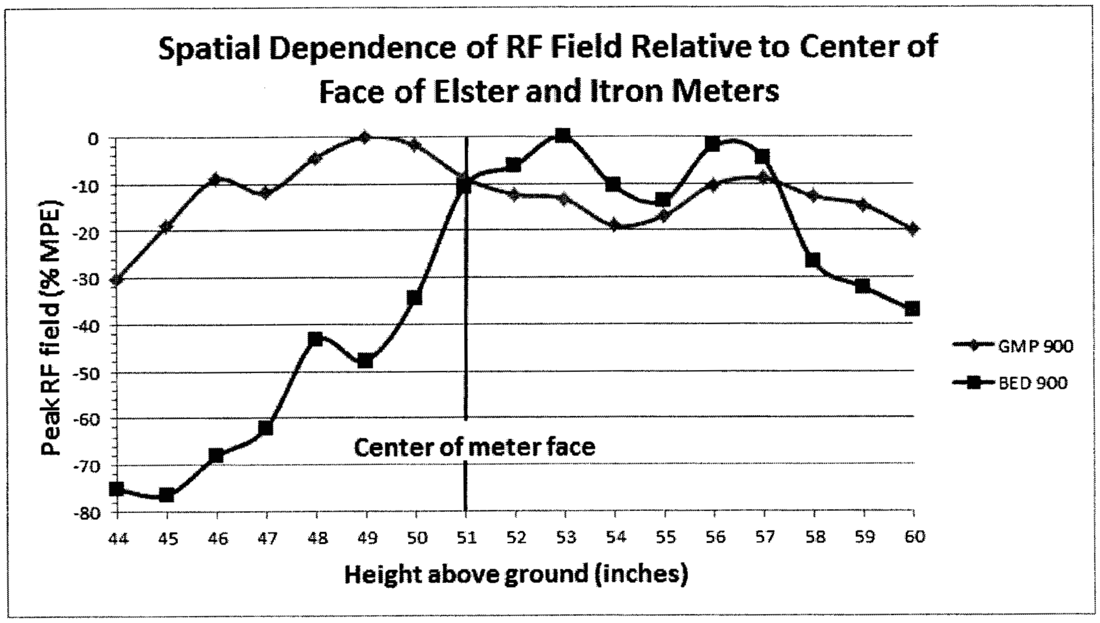

Figure 72. The measured spatial dependence of 900 MHz band RF fields produced at one foot from the GMP Elster and BED Itron smart meters along a vertical line extending from 44 inches to 60 inches above the floor.

Smart meter RF emissions can be put in perspective by comparing their emission levels to RF fields associated with other kinds of sources. A few highlights of such a comparison include:

Discussion

- The likely strongest source of RF exposure in the home is the microwave oven that can result in average RF fields exceeding 6% of the FCC MPE at one foot from the oven and greater than 1% of the MPE at three feet.

- Wireless routers can result in average field levels of as much as 0.0011% of the MPE in the 2.4 GHz band at a distance of one foot (based on a measured peak field of 0.017% of the MPE and a duty cycle of 6.5%).

- The prevalence of FM radio broadcast stations leads to RF field levels that are roughly uniform over the body dimensions, operate with 100% duty cycle and can be in the range of about 1% of the MPE (greatest average value of 0.6% of the MPE was found at environmental site 14 in the Burlington area). This value of field is almost 9 times greater than the time-averaged field at one foot in front of the maximum field smart meter and 400 times the smart meter field at 10 feet from a smart meter.

- The most likely source of personal exposure to RF today is the mobile (cell) phone. Cell phones make use of transceivers that, in terms of power and frequencies used, are not very different from the transceivers in smart meters. Thus, one would not expect that there would be very much difference in exposure between the two devices except for the fact that cell phones are intended to be used against the body while smart meters are not. In a measurement of the spatially averaged RF field over a six-foot vertical dimension, with the phone positioned at five feet above the floor, the field was found to be equivalent to 0.070% of the MPE (Figure 62). Interestingly, this is in quite close agreement with the value obtained for the maximum field smart meter in terms of time-averaged field, including spatial averaging of 0.068% of the MPE. The local energy absorption rate associated with use of the cell phone, however, because of the proximity of the phone to the body during typical use, will result in a far greater local SAR than the smart meter positioned at one foot in front of a person.

Interestingly, when a large group of smart meters are installed together in a bank, such as on an apartment building, the instantaneous peak RF field produced is no different from that of a single meter. However, the time-averaged value of RF field can be greater simply due to the number of meters present. The measurement data collected as part of this study did not, however, reveal any duty cycles of the aggregate RF fields of a meter bank greater than that associated with a single end point meter during its reporting of historical data to the Gatekeeper or Cell Router. The aggregation of smart meters in a bank does not necessarily imply that the long-term time-averaged RF field will be any greater than a high activity end point meter because the smart meters are not interrogated in a physically sequential manner. While one meter in the bank may respond with data, the next meter queried may be located substantially far from the bank of meters and, consequently, its fields are negligible in comparison to those immediately at the bank.

RF fields found near data collection points in both the GMP and BED service territories were unremarkable other than for the amount of data traffic observed. Because of the elevated height of these Gatekeepers and Cell Routers, RF field emissions are greatly reduced from those found immediately in front of smart meters. As such, the data collection points do not represent any significant increase in potential RF exposure. This is related to the fact that, in the GMP territory, the WWAN connection operates at high speed, thereby allowing for overall low duty cycles when it is transmitting large amounts of data back to the utility company. In the BED region, all data collected by the Cell Router is routed back to the company via a fiber optic network and no additional RF is involved.

Smart meters emit short duration pulses of RF energy in their communication with other meters and data collection points. These emissions generally happen all through the day. Besides the normal three (in the case of BED) or four (in the case of GMP) times a day that electric energy consumption data are reported back to a data collection point for subsequent transmission to the company, smart meters must maintain their organization within the RF LAN to which they belong and this necessitates the transmission of beacon signals from time to time. Additionally, each meter can, when required by the mesh network, assist neighboring smart meters by transmitting the neighbor's data on to another meter or data collection point. Further, the HAN radio can produce pulsed fields in its search for and communication with IHDs. All of this means that most smart meters remain relatively active in terms of brief signals being transmitted. However, the total amount of time that a smart meter transmits during a day is small but non-zero. For instance, the greatest 30-minute duty cycle found for the GMP meters in the` 900 MHz band of 3.55% means that, if this meter were to continue to operate at this rate, the meter would be active for 3.55% of each 30 minute window of time. This corresponds to 63.8 seconds during each half-hour period that it may be active at this level. If this high duty cycle were to be maintained for, say, two hours, four times per day, this would amount to some 17 minutes of transmit time during the day. It is likely that there would be some additional network overhead activity that would increase the total transmit time but, suffice it to say, actual emission of RF fields occurs only for a small fraction of the day. For most meters within the mesh network, the activity will be far less than for those meters that happen to lie within one hop to the data collector since it is these meters that do the most work in transferring RF LAN data.

An evaluation of low frequency electric and magnetic fields of the smart meters that could be a product of switch mode power supplies within the meters showed that the two test meters exhibited different magnitudes of fields but in both cases, all such fields were substantially less than applicable science based guidelines and standards for exposure. Recommended exposure limits at low frequencies have been recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [13] and the IEEE [14]. Of the two, the more stringent values are those of ICNIRP which are summarized in Table 12 for sinusoidal electric and magnetic fields for general public exposure.

Table 12. Recommended public exposure limits (reference levels) from ICNIRP [13] for sinusoidal low frequency electric and magnetic fields for whole-body exposure.

Frequency range	Electric fields (V/m) RMS	Magnetic fields (μT) RMS
1 Hz – 8 Hz	5000	40,000
8 Hz – 25 Hz	5000	625
25 Hz – 50 Hz	5000	200
50 Hz – 400 Hz	5000	200
400 Hz – 3 kHz	625	200
3 kHz – 10 MHz	83	27

The low frequency measurement data for the two smart meters in the various ICNIRP defined frequency ranges are very substantially less than the recommended values contained in Table 12.

Smart meters emit pulses of RF energy similar to many other everyday sources in the environment. For instance, wireless routers continuously transmit beacon pulses at a rate of 10 pulses per second (10 Hz). Signals from airport and long range air traffic control radars and Doppler weather radar systems produce a constant stream of pulsed RF fields to which individuals may be exposed. For systems such as radars, high pulse repetition frequencies (PRFs) are often used that can range from several hundred Hz to greater than one kilohertz.

Conclusions

Conclusions

A number of field measurement studies conducted by one of the authors address RF emissions from wireless smart meters [1, 2, 3, 9, 15]. All of these studies have demonstrated that the potential exposures that could result from proximity to the subject smart meter emissions comply with the limits set by the FCC. This study is no different.

The RF emissions produced by the smart meters deployed by GMP and BED were found to comply with the public exposure regulations of the FCC by a wide margin, typically by a factor of approximately 1500 times, even at one foot from the meters. The measurement data show that the RF field emissions decrease sharply with increasing distance from the smart meters. At distances more likely associated with common day-to-day exposures to smart meter emissions, the RF fields become even dramatically less. For example, at a distance of 10 feet in front of a meter, the RF field drops to approximately 76,000 times less than the FCC limit. Relative to the actual biological hazard thresholds, not the MPE which contains a safety factor of 50 for the general public, the RF fields at one foot and ten feet from a smart meter are some 75,000 times and 3,800,000 times less respectively.

Detailed measurements of RF fields found inside of smart meter equipped homes showed that the highest fields (typically directly behind the meter but inside the home) were comparable to that found at 10 feet in front of the meter. However, the average of residential indoors smart meter RF fields measured in this study was more than 1.7 million times less than the FCC public exposure limit.

Potential exposure to RF emissions of banks of smart meters was not found to be significantly greater than that of a single meter in terms of the peak value of field but the time-averaged level of RF field can increase simply because of the larger number of meters. However, there is no general correlation between overall higher average RF fields associated with large banks of meters since the greatest duty cycle of any given smart meter appears to be more related to a specific meter's position within the wireless network's hierarchy, i.e., how close it is, from a communications perspective, to its designated data collection point. Hence, a single meter that serves to relay energy consumption data from many other meters to the data collection point can exhibit a greater time-averaged RF field than a large group of meters that are not close, network wise, to a data collection point.

The greatest measured smart meter duty cycles found through this investigation were in the 3-4% range and are comparable to those values determined from statistical analysis of meter transmission activity derived from electric utility data management software systems in earlier studies [1, 2]. Average duty cycles of most meters are substantially less than 1%.

Conclusions

Exposure, in terms of instantaneous peak as well as time-averaged RF fields, caused by deployed smart meters in Vermont is small in comparison to that related to many other sources of RF fields in the environment. For instance, local values of long term, time-averaged RF fields (as a fraction of the MPE) from FM radio broadcasting can, in some areas, be as much as ten to hundreds of times greater than those values found immediately near smart meters. The common use of normal appliances within a home or office, such as microwave ovens and wireless routers, can lead to RF fields that are comparable to or substantially greater than those produced by smart meters. This applies to the use of mobile phones as well; both mobile phones and smart meters operate with roughly the same transmitter peak powers. In this context, however, mobile phones are normally held against the head during use while smart meters are not.

Low frequency electric and magnetic fields produced by the smart meters and their internal switch mode power supplies, at one foot from the meters, were substantially smaller in value than the recommended limits of the ICNIRP guidelines [13].

The communications technology used by smart meters makes use of low power, pulsed RF transmissions that result in weak RF fields by comparison to currently scientifically based human exposure limits. The pulsed nature of smart meter emissions is not very dissimilar to other sources such as wireless routers, mobile phones or air traffic control and weather radars, for example. Pulse repetition rates from 10 Hz for routers sitting idle, 217 Hz for GSM type mobile phones and up to more than a kilohertz for radars characterize many of the signals found in the everyday environment.

The operation of the HAN radios in smart meters produces additional RF emissions for communication with IHDs but the extremely low duty cycle and lower transceiver power levels result in very weak additions to the overall fields that individuals may experience near them.

Applying the highest indicated results from the measurements performed in this study, the RF fields associated with the currently deployed smart meters in the GMP and BED service territories are small when compared to the limits set by the FCC. It is concluded that any potential exposure to the investigated smart meters will comply with the FCC exposure rules by a wide margin.

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Appendix A

RF Exposure Report Prepared for the FCC on Behalf of Elster Solutions, LLC
By
TUV Rheinland North America

Appendix A

TÜVRheinland®
Precisely Right.

RF Exposure Report

EUT Name: Rex2 Power Meters
EUT Model: RX2EA4, RX2EA4-I
FCC ID: QZC-RX2EA4 , QZC-RX2EA4I

FCC Title 47, Part 15.247(i), 1.1307(b), and 1.1310

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Report/Issue Date: 9 February 2010
Report Number: Supplement to 30953899.001 - MPE

1 RF Exposure Measurement (Mobile Device) 15.247(i)

1.1 Test Methodology

In this document, we try to prove the safety of radiation harmfulness to the human body for our product. The limit for Maximum Permissible Exposure (MPE) specified in FCC 1.1310 is followed. The Gain of the antenna used in this product is measured in a Semi-Anechoic Chamber, and also the maximum total power input to the antenna is measured. Through the Friis transmission formula (see section 4.9.6) and the maximum gain of the antenna, we can calculate the distance, away from the product, where the limit of MPE is reached.

Although the Friis transmission formula is a far field assumption, the calculated result of that is an over-prediction for near field power density. We will take that as the worst case to specify the safety range.

1.2 RF Exposure Limit

According to FCC 1.1310 table 1: The criteria listed in the following table shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in 1.1307(b)

LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Average Time (minutes)
(A)Limits For Occupational / Control Exposures				
300-1500	...	...	F/300	6
1500-100,000	...	...	5	6
(B)Limits For General Population / Uncontrolled Exposure				
300-1500	...	...	f/1500	6
1500-100,000	...	...	1.0	30

f = Frequency in MHz

1.3 EUT Operating condition

The software provided by Manufacturer enabled the EUT to transmit data at lowest, middle and highest channel individually.

1.4 Classification

The antenna of the product, under normal use condition, is at least 20cm away from the body of the user. Warning statement to the user for keeping at least 20cm or more separation distance with the antenna should be included in users manual. Therefore, this device is classified as a **Mobile Device**.

1.5 Test Results

1.5.1 Antenna Gain

The maximum Gain measured in Semi-Anechoic Chamber is 5.64 dBi or 3.66 (numeric).

1.5.2 Output Power into Antenna & RF Exposure value at distance 20cm:

Calculations for this report are based on highest power measurement and the highest gain of the antenna.
Limit for MPE (from FCC part 1.1310 table 1) is f (MHz) / 1500 = 927.6 / 1500 = 0.62 mW/cm^2

Highest Pout is 250mW, highest antenna gain (in linear scale) is 3.27, R is 20cm, and f = 927.6 MHz

Pd = (250*3.66) / (1600π) = **0.182 mW/cm^2**, which is 0.438 mW/cm^2 below to the limit.

As originally tested, the EUT was found to be compliant to the requirements of the test standard(s).

1.6 Sample Calculation

The Friis transmission formula: Pd = (Pout*G) / (4*π*R^2)

Where;

Pd = power density in mW/cm2
Pout = output power to antenna in mW
G = gain of antenna in linear scale
$\pi \approx 3.1416$
R = distance between observation point and center of the radiator in cm

Ref. : David K. Cheng, *Field and Wave Electromagnetics*, Second Edition, Page 640, Eq. (11-133).

Appendix B

RF Exposure Report Prepared for the FCC on Behalf of Iton
By
Advanced Compliance Solutions (ACS)

ACS
Excellence in Compliance Testing

Certification Exhibit

FCC ID: SK9AMI6
IC: 864G-AMI6

FCC Rule Part: 15.247
IC Radio Standards Specification: RSS-210

ACS Report Number: 10-0158.W06

Manufacturer: Itron Electricity Metering, Inc.
Model: AMI6

RF Exposure

5015 B.U. Bowman Drive Buford, GA 30518 USA Voice: 770-831-8048 Fax: 770-831-8598

Appendix B

General Information:

Applicant:	Itron Electricity Metering, Inc.
ACS Project:	10-0158
Device Category:	Mobile
Environment:	General Population/Uncontrolled Exposure
Simultaneous Transmission:	Yes

Technical Information 900 MHz LAN Radio
Antenna Type: Quarter Wave Embedded Slot Antenna
Antenna Gain: 2.2dBi
Transmitter Conducted Power: 24.83dBm
Maximum System EIRP: 27.03dBm (505mW)

Technical Information 802.15.4 Zigbee Radio
Antenna Type: Quarter Wave Embedded Slot Antenna
Antenna Gain: 3.8dBi
Transmitter Conducted Power: 18.94dBm
Maximum System EIRP: 22.74dBm (188mW)

MPE Calculation
The Power Density (mW/cm^2) is calculated as follows:

$$S = \frac{PG}{4\pi R^2}$$

Where:
S = power density (in appropriate units, e.g. mW/cm2)
P = power input to the antenna (in appropriate units, e.g., mW)
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna (appropriate units, e.g., cm)

MPE Calculator for Mobile Equipment Limits for General Population/Uncontrolled Exposure*							
Transmit Frequency (MHz)	Radio Power (dBm)	Power Density Limit (mW/Cm2)	Radio Power (mW)	Antenna Gain (dBi)	Antenna Gain (mW eq.)	Distance (cm)	Power Density (mW/cm^2)
902.25	24.83	0.60	304.09	2.2	1.660	20	0.100
2475	18.94	1.00	78.34	3.8	2.399	20	0.037

Summation of Power Densities – Simultaneous Transmissions
This device contains multiple transmitters which can operate simultaneously and therefore the maximum RF exposure is determined by the summation of power densities. The 900 MHz LAN and 2.4GHz Zigbee radio can operate simultaneously there it is appropriate to include both of those power density values in the summation of power densities.

The maximum power density is calculated by a summation of power densities for each simultaneous transmission combination as follows:

900MHz LAN:	0.100 (mW/cm^2)
2.4GHz Zigbee:	0.037 (mW/cm^2)
TOTAL:	0.137 (mW/cm^2)

Appendix B

Installation Guidelines
The installation manual should contain text similar to the following advising how to install the equipment to maintain compliance with the FCC RF exposure requirements:

RF Exposure
In accordance with FCC requirements of human exposure to radio frequency fields, the radiating element shall be installed such that a minimum separation distance of 20 centimeters will be maintained.

Conclusion
This device complies with the MPE requirements by providing adequate separation between the device, any radiating structure and the general population.

Appendix C
Calibration Certification of the Narda SRM-3006 Selective Radiation Meter

Appendix C

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Calibration Certificate

Narda Safety Test Solutions hereby certifies that the object referred to in this certificate has been calibrated by qualified personnel using Narda's approved procedures. The calibration was carried out in accordance with a certified quality management system which conforms to ISO 9001

OBJECT	Selective Radiation Meter, Basic Unit, SRM-3006
MANUFACTURER	Narda Safety Test Solutions GmbH
PART NUMBER (P/N)	3006/01
SERIAL NUMBER (S/N)	D-0069
CUSTOMER	
CALIBRATION DATE	2010-10-13
RESULT ASSESSMENT	within specifications
AMBIENT CONDITIONS	Temperature: (23 ± 3)°C Relative humidity: (25 to 75) %
CALIBRATION PROCEDURE	3006-8701-00A

ISSUE DATE: 2010-10-18

MANAGEMENT SYSTEM

P. Geyer
CALIBRATED BY:
Paul Geyer

i. A. [signature]
AUTHORIZED SIGNATORY:

Certified by DQS against ISO 9001:2008 (Reg.-No. 099379 QM08)

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OBJECT

The spectrum analyzer is based on digital signal processing. Small frequency spans were measured at fixed local oscillator (1st LO) settings using discrete Fourier transformation (DFT). The LO was also swept for larger frequency spans.
A memory chip contains correction values for various frequencies and object settings. The stored values were taken into account automatically during the measurement.

METHOD OF MEASUREMENT

Calibration using the reference standard. The output power level of the synthesized CW generator was adjusted and calibrated using power sensors as reference standards.
The frequency of the generator was calibrated using a frequency counter.

The reflection of the object was measured directly using a vector network analyzer (VNA) calibrated by means of a calibration kit. The measuring equipment and the associated uncertainty were verified using a reference standard (verification kit).

CALIBRATION PROCEDURE

The object was connected to the signal source instead of the power sensors in order to calibrate it.

Measurement of the RF frequency response was made with different settings of the measurement range. As a result, the measured values also include the effects due to the "input attenuator" and the "reference level accuracy".
The calibration factor was calculated for various frequencies and settings from a comparison between the "actual level" and the "indicated level".

All the selection filters are digital filters. No calibration of the filters is necessary.

TRACEABILITY

The calibration results are traceable to the International System of Units (SI) in accordance with ISO/IEC 17025. The measuring equipment used for calibration is traceable through the reference standards listed below.

STANDARD	MANUFAC-TURER	MODEL	SERIAL NUMBER	ID	CERTIFICATE	NEXT CAL. DATE	TRACE
HF-MILLIVOLTMETER	R&S	URV 55	100143	913	0116 DKD-K-16101 2010-05	2012-05	DKD
DIODE POWER SENSOR	R&S	NRV Z4	100199	956	0104 DKD-K-16101 2010-05	2012-05	DKD
THERMAL POWER SENSOR	R&S	NRV Z51	101777	1635	0264 DKD-K-16101 2008-11	2010-11	DKD
MISMATCH VSWR 1,2 (f)	Rosenberger	--	01237	552-3	12996 DKD-K-00201 2008-05	#	DKD
FREQUENCY COUNTER	Advantest	R5362B	120700137	923	15137 DKD-K-00201 2009-09	#	DKD

\# Reference standard; not used for routine calibration

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UNCERTAINTY

The reported expanded uncertainty U is based on a standard uncertainty multiplied by a coverage factor k = 1.96, providing a level of confidence of approximately 95 %. The uncertainty evaluation has been carried out in accordance with the "Guide to the Expression of Uncertainty in Measurement" (GUM).
The reported measurement uncertainty is derived from the uncertainty of the calibration procedure and the object during calibration, and makes no allowance for drift or operation under other environmental conditions.

MEASURING CONDITIONS

The following results were obtained after adjustment of the object under calibration.
These values are within the setting ranges defined by the manufacturer.

RESULTS

1	FREQUENCY RESPONSE (IF):	passed
2	FREQUENCY RESPONSE (RF):	passed
3	OUT-OF-BAND RESPONSE:	passed
4	FREQUENCY ACCURACY	passed
5	NOISE SIDEBAND (SSB):	passed
6	SPURIOUS (input related)	passed
7	SPURIOUS (residual)	passed
8	NOISE FLOOR:	passed
9	INTERMODULATION REJECTION (2nd and 3rd order):	passed
10	INPUT RETURN LOSS:	passed

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APPENDIX

FREQUENCY RESPONSE (RF)

The generator was set to the *Fgen*. The object settings were *Fspan*, *RBW*, and *Fcent*.
The measurements were made at different settings of the measurement range *MR*. The nominal level of the generator was -32 dBm (for *MR* < -5 dBm) and -7 dBm (for *MR* ≥ -5 dBm), respectively. The frequency response *G* was calculated as the difference of the actual generator level L_{actual} and the indicated level $L_{indicated}$ according to the following equation: $G/\mathrm{dB} = (L_{indicated} - L_{actual})/\mathrm{dBm}$

Frequency in MHz	Fspan in MHz	RBW in kHz	Fcent in MHz	MR												U
				-30	-28	-25	-20	-15	-10	-5	0	5	10	15	20	
0.00901	0.002	0.01	0.01	0	0	0	-0.01	-0.01	0	0	0	0	0	-0.01	-0.01	0.2
0.012	0.006	0.5	0.012	0.01	0.01	0.01	0	0	0.01	0.01	0.01	0	0.01	0	0	0.2
0.02	0.02	2	0.02	0.01	0	0	0	-0.01	0.01	0.01	0	0	0	0	-0.01	0.2
0.04	0.02	2	0.04	0	0	0	-0.01	-0.01	0	0	0	0	0	0	-0.01	0.2
0.1	0.02	2	0.1	0	0	0	-0.01	-0.01	0	0	0	-0.01	-0.01	-0.01	-0.01	0.2
0.5	0.02	2	0.5	0	0	0	-0.01	-0.01	0	0	0	-0.01	-0.01	-0.01	-0.01	0.2
2	0.02	2	2	0	0	0	-0.01	-0.01	0	0.01	0	0	0	0	0	0.2
10	0.02	2	10	0.01	0.01	0	0	0	0.01	0.01	0.01	0	0	0	0	0.2
20	0.02	2	20	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0	0	0.2
30	0.02	2	30	0.01	0.01	0	0	0	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.2
31.233	26.75	30	44.578	-0.11	-0.19	-0.15	-0.18	-0.29	-0.12	-0.14	-0.15	-0.29	0	-0.14	-0.21	0.2
36.1	26.75	30	44.578	-0.03	-0.11	-0.07	-0.13	-0.17	-0.06	-0.08	-0.1	-0.17	-0.02	-0.1	-0.14	0.2
40	0.02	2	40	0.01	0.01	0	0	0	0	0.01	0.01	0	0	-0.01	-0.01	0.2
44.1	26.75	30	44.578	0.04	-0.01	-0.01	-0.03	-0.03	0.01	0	-0.01	-0.02	-0.04	-0.03	-0.06	0.2
50	0.02	2	50	0.01	0	0	0	0	0.02	0.01	0.01	0	0.01	0.01	0.02	0.2
52.1	26.75	30	44.578	0.03	0	-0.01	-0.05	-0.01	0	-0.01	-0.03	0	-0.11	-0.07	-0.07	0.2
57.9948	0.02	2	57.9868	0.01	0	0	-0.01	-0.01	-0.01	0	0	-0.01	-0.01	-0.03	-0.05	0.2
58.344	26.75	30	44.999	-0.02	-0.04	-0.07	-0.12	-0.05	-0.05	-0.06	-0.09	-0.05	-0.18	-0.13	-0.11	0.2
60.1	26.75	30	60.1	0.02	0.01	0.01	0	-0.01	0	0.01	0.01	0.01	0	-0.01	-0.03	0.2
100.1	26.75	30	100.1	0.02	0.01	0.01	0.01	0	0	0.02	0.01	0	0	-0.02	-0.02	0.2
200.1	26.75	30	200.1	0	0	0	-0.01	-0.02	-0.02	0	-0.01	-0.02	-0.02	-0.03	-0.04	0.2
300.1	26.75	30	300.1	0	0	0	0	-0.01	0	0.01	0	0	0	-0.02	-0.02	0.2
400.1	26.75	30	400.1	0	0	-0.01	-0.01	-0.02	-0.02	0	-0.01	-0.01	-0.02	-0.02	-0.05	0.2

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Frequency in MHz	Fspan in MHz	RBW in kHz	Fcent in MHz	MR												U
				-30	-28	-25	-20	-15	-10	-5	0	5	10	15	20	
500.1	26.75	30	500.1	-0.01	-0.01	-0.01	-0.01	-0.02	-0.03	0	-0.01	-0.01	-0.02	-0.03	-0.04	0.2
600.1	26.75	30	600.1	0	0	0	-0.01	-0.01	-0.02	0	-0.01	-0.01	-0.01	-0.02	-0.04	0.2
700.1	26.75	30	700.1	0	0	-0.01	-0.01	-0.02	-0.02	-0.01	-0.01	-0.02	-0.02	-0.04	-0.04	0.2
800.1	26.75	30	800.1	0	0	-0.01	-0.01	-0.02	-0.03	-0.01	0	-0.01	-0.02	-0.04	-0.05	0.2
900.1	26.75	30	900.1	-0.01	-0.01	-0.02	-0.01	-0.02	-0.03	-0.01	-0.01	-0.01	-0.03	-0.03	-0.05	0.2
1000.1	26.75	30	1000.1	-0.02	-0.03	-0.02	-0.03	-0.04	-0.05	-0.02	-0.03	-0.03	-0.04	-0.05	-0.08	0.2
1100.1	26.75	30	1100.1	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02	-0.03	-0.04	-0.06	0.2
1200.1	26.75	30	1200.1	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	-0.03	-0.04	-0.04	-0.06	0.2
1300.1	26.75	30	1300.1	-0.01	-0.01	-0.01	-0.02	-0.03	-0.02	-0.02	-0.02	-0.02	-0.03	-0.04	-0.05	0.2
1400.1	26.75	30	1400.1	0.01	0.02	0.02	0.01	0.01	0	0.01	0.01	0	0	-0.01	-0.03	0.2
1500.1	26.75	30	1500.1	0.03	0.03	0.03	0.02	0.02	0.01	0.03	0.03	0.02	0.01	0	0	0.2
1600.1	26.75	30	1600.1	0.02	0.02	0.01	0.01	0.01	0	0.03	0.02	0.01	0	0	-0.01	0.2
1700.1	26.75	30	1700.1	0.06	0.06	0.06	0.05	0.05	0.04	0.07	0.06	0.04	0.04	0.03	0.02	0.2
1800.1	26.75	30	1800.1	0.02	0.02	0.02	0.01	0	0.01	0.01	0.01	0	0	-0.01	-0.04	0.2
1900.1	26.75	30	1900.1	0.01	0	0	-0.01	-0.02	-0.02	0	0	-0.01	-0.01	-0.02	-0.04	0.2
2000.1	26.75	30	2000.1	0.01	0	0.01	0.01	-0.01	-0.01	0.01	0.01	0	0	-0.02	-0.03	0.2
2100.1	26.75	30	2100.1	0.02	0.01	0.01	0	-0.01	0	0.01	0.01	0.01	0	-0.01	-0.03	0.2
2200.1	26.75	30	2200.1	0.01	0.02	0.01	0.01	-0.01	0	0.02	0.01	0	0	-0.01	-0.03	0.2
2300.1	26.75	30	2300.1	0.02	0.02	0.01	0.01	0	0	0.02	0.02	0.01	0.01	-0.01	-0.01	0.2
2400.1	26.75	30	2400.1	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.03	0.03	0.01	0	-0.03	0.2
2500.1	26.75	30	2500.1	-0.01	-0.01	0	-0.02	-0.02	-0.02	0	0	-0.01	-0.02	-0.03	-0.04	0.2
2600.1	26.75	30	2600.1	0.01	0	0.01	0	-0.01	0	0.02	0.01	0	0	-0.01	-0.03	0.2
2700.1	26.75	30	2700.1	0.04	0.04	0.03	0.02	0.02	0.03	0.04	0.03	0.03	0.02	0.02	-0.01	0.2
2800.1	26.75	30	2800.1	0.05	0.05	0.04	0.03	0.03	0.04	0.05	0.05	0.04	0.03	0.02	0.01	0.2
2900.1	26.75	30	2900.1	0.02	0.02	0.02	0.01	0	0.01	0.04	0.04	0.03	0.03	0.01	0	0.2
2999.9	26.75	30	2999.9	0.01	0.02	0.03	0	0.01	0.02	0.03	0.03	0.01	0.02	0	-0.01	0.2
3002.1	26.75	30	3002.1	-0.04	-0.02	-0.02	-0.01	-0.03	0	0.01	0.01	-0.01	0	-0.02	-0.03	0.2
3100.1	26.75	30	3100.1	-0.02	-0.02	-0.02	-0.02	-0.02	0	0	0.01	-0.01	0	-0.01	-0.03	0.2
3200.1	26.75	30	3200.1	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	0.03	0.02	0.02	0.02	0.01	-0.01	0.2
3300.1	26.75	30	3300.1	0	0.01	0.01	0	0	0.02	0.03	0.01	0.03	0.02	0.02	0	0.2
3400.1	26.75	30	3400.1	0	0	-0.01	-0.02	-0.02	0.02	0.03	0.01	0.01	0.01	0	-0.02	0.2
3500.1	26.75	30	3500.1	0.01	0.01	0	0	-0.01	0.02	0.04	0.02	0.03	0.02	0.01	-0.01	0.2

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Frequency in MHz	Fspan in MHz	RBW in kHz	Fcent in MHz	MR												U
				-30	-28	-25	-20	-15	-10	-5	0	5	10	15	20	
3600.1	26.75	30	3600.1	0	0	-0.01	0	-0.02	0.01	0.02	0.02	0.03	0.02	0	-0.02	0.2
3700.1	26.75	30	3700.1	-0.02	-0.02	-0.02	-0.02	-0.03	0	0.03	0.01	0.01	0.01	0	-0.02	0.2
3800.1	26.75	30	3800.1	-0.02	-0.01	-0.02	-0.02	-0.04	0.01	0.02	0.01	0.01	0	-0.01	-0.03	0.2
3900.1	26.75	30	3900.1	-0.01	-0.01	-0.02	-0.02	-0.02	0	0.02	0.02	0.01	0.01	-0.01	-0.02	0.2
4000.1	26.75	30	4000.1	-0.02	-0.01	-0.01	-0.02	-0.03	0.01	0.01	0.01	0	0	-0.02	-0.04	0.2
4100.1	26.75	30	4100.1	0.02	0.01	0.01	0	0	0.04	0.05	0.05	0.04	0.03	0.01	0.02	0.2
4200.1	26.75	30	4200.1	0.03	0.03	0.03	0.03	0.01	0.06	0.07	0.05	0.07	0.04	0.05	0.02	0.2
4300.1	26.75	30	4300.1	0.03	0.04	0.03	0.03	0.01	0.04	0.06	0.06	0.06	0.04	0.03	0.01	0.2
4400.1	26.75	30	4400.1	0	-0.01	-0.01	-0.01	-0.01	0.01	0.03	0.03	0.02	0.01	-0.01	-0.05	0.2
4500.1	26.75	30	4500.1	-0.02	-0.03	-0.04	-0.04	-0.05	-0.02	0.01	0.01	0	-0.02	-0.04	-0.05	0.2
4600.1	26.75	30	4600.1	0	0	0	0	-0.01	0	0.04	0.03	0.01	0	0.01	-0.03	0.2
4700.1	26.75	30	4700.1	0.02	0.01	0.01	0	-0.01	0.01	0.04	0.03	0.03	0.01	0.01	-0.02	0.2
4800.1	26.75	30	4800.1	-0.01	0	-0.02	-0.01	-0.03	-0.02	0.01	0	-0.01	-0.02	-0.06	-0.08	0.2
4900.1	26.75	30	4900.1	-0.04	-0.03	-0.04	-0.06	-0.07	-0.05	-0.02	-0.03	-0.04	-0.06	-0.06	-0.09	0.2
5000.1	26.75	30	5000.1	-0.03	-0.03	-0.04	-0.04	-0.05	-0.04	-0.01	-0.02	-0.04	-0.04	-0.05	-0.07	0.2
5100.1	26.75	30	5100.1	-0.02	-0.02	-0.01	-0.01	-0.04	-0.02	-0.01	-0.01	-0.01	-0.03	-0.04	-0.09	0.2
5200.1	26.75	30	5200.1	0	0	0.01	0	-0.03	0	0	0.01	-0.01	-0.01	-0.03	-0.05	0.2
5300.1	26.75	30	5300.1	0.03	0.02	0.03	0.01	0	0.01	0.02	0.02	0.01	0.01	-0.02	-0.06	0.2
5400.1	26.75	30	5400.1	0.01	0.02	0.01	0.01	-0.01	0	0.02	0	0	0	-0.03	-0.07	0.2
5500.1	26.75	30	5500.1	0.01	0.01	0.02	0.01	0	-0.02	0.02	0.01	0	-0.01	-0.03	-0.05	0.2
5600.1	26.75	30	5600.1	0.03	0.04	0.02	0.03	0.01	-0.02	0.02	0.02	0.02	0.01	-0.02	-0.04	0.2
5700.1	26.75	30	5700.1	0.03	0.03	0.04	0.03	0.03	-0.01	0.03	0.01	0	0.02	0	-0.04	0.2
5800.1	26.75	30	5800.1	0.03	0.04	0.04	0.03	0.02	0	0.02	0.01	0.01	0	-0.02	-0.04	0.2
5900.1	26.75	30	5900.1	0.04	0.04	0.04	0.02	0.01	-0.02	0.01	-0.01	0	-0.02	-0.03	-0.06	0.2
5986.1	26.75	30	5986.625	0.05	0.05	0.05	0.04	0.04	0	0.02	0.02	0.01	0	-0.01	-0.06	0.2

Frequency Response *G* and Uncertainty *U* in dB

Appendix C

Narda Safety Test Solutions GmbH
Sandwiesenstrasse 7 . D-72793 Pfullingen . Germany
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Calibration Certificate

Narda Safety Test Solutions hereby certifies that the referenced equipment has been calibrated by qualified personnel to Narda's approved procedures. The calibration was carried out within a certified quality management system conforming to ISO 9001.

Object	**Antenna, Three-Axis, E-Field, 27 MHz to 3 GHz**
Part Number (P/N)	**3501/03**
Serial Number (S/N)	**K-0242**
Manufacturer	Narda Safety Test Solutions GmbH
Customer	
Date of Calibration	07-Okt-2010
Results of Calibration	Test results within specifications
Confirmation interval recommended	24 Months
Ambient conditions	Temperature: (23 ± 3) °C Relative humidity: (20 to 60) %
Calibration procedure	3000-8702-00A

Pfullingen, 07-Okt-2010

MANAGEMENT SYSTEM

P. Geyer
Person in charge
Geyer

i. A.
Head of Laboratory
J. v. Freeden

Certified by DQS according to ISO 9001:2008 (Reg.-No. 099379 QM08)

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Measurements

The calibration of RF field strength probes involves the generation of a calculable linearly polarized electromagnetic field, approximating to a plane wave, into which the device is placed.
The RSS value of three axis is used.

At each test frequency, the probe is orientated in the analytic angle (54.74 degrees between probe axis and electric field vector) and rotated 360 degrees. The noted indicated output voltage is calculated from the geometric mean of the minimum and maximum readings during rotation. The antenna factor is calculated from the ratio of the applied field strength to the output voltage (nominal impedance 50 Ohm). The minimum and maximum readings during rotation are further used to calculate the ellipse ratio.
A power meter head is connected by means of an ferrite beaded 50 Ohm coaxial cable.

A Crawford TEM cell is used to generate the known field at frequencies up to 100 MHz. The field strength is derived from the TEM cell's properties and from the output power of the cell.
Over the frequency range from 200 MHz to 1.6 GHz, the probe is positioned in front of a double balanced ridge horn antenna. The field strength is set to a known value by means of a calibrated E-field reference probe.
Above 1.7GHz the probe is positioned with the boresight of a linearly polarized horn antenna. The field strength is derived from the mechanical dimensions and the input power of the antenna.

The antenna factor is permanently stored in the antenna connector memory. When combined with the SRM basic unit (BN 3001 series) the frequency response of the antenna is automatically compensated.

Uncertainties

The measurement uncertainty stated in this document is the expanded uncertainty with a coverage factor of 2 (corresponding, in the case of normal distribution, to a confidence probability of 95%).

The uncertainty analysis for this calibration was done in accordance with the ISO-Guide (Guide to the expression of Uncertainty in Measurement). The measurement uncertainties are derived from contributions from the measurement of power, impedance, attenuation, mismatch, length, frequency, stability of instrumentation, repeatability of handling and field uniformity in the field generators (TEM cell and anechoic chamber).

This statement of uncertainty applies to the measured values only and does not make any implementation or include any estimation as to the long-term stability of the calibrated device.

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Traceability of Measuring Equipment

The calibration results are traceable to National Standards, which are consistent with the recommendations of the General Conference on Weights and Measure (CGPM), or to standards derived from natural constants. Physical units, which are not included in the list of accredited measured quantities such as field strength or power density, are traced to the basic units via approved measurement and computational methods.
The equipment used for this calibration is traceable to the reference listed above and the traceability is guaranteed by ISO 9001 Narda internal procedure.

Reference- / Working- Standard	Manu facturer	Model	Serial Number	Certificate Number	Cal Due Date	Trace
Power Sensor	R&S	NRV-Z4	100122	0171 DKD-K-16101 2008-11	2010-11	DKD
RF-Millivoltmeter	R&S	URV55	100213	0224 DKD-K-16101 2010-08	2012-08	DKD
Set-Up "A" (1800 MHz to 3 GHz)						
Calliper	Preisser	0-800mm	310121016	649724 DKD-K-12001 06-05	#	DKD
Power Sensor	agilent	8481A	US37299951	1-2217165994-1	2011-08	UKAS147
Power Sensor	agilent	8481A	US37299952	1-2217214152-1	2011-09	UKAS147
Power Meter	agilent	E4419A	MY40330449	1-2217141092-1A	2011-09	UKAS147
Set-Up "B" (200 MHz to 1600 MHz)						
E-Field Reference Probe	Narda	Type 9.2	V-0017	51200637E	#	SIT08
Power Sensor	agilent	8481A	US37299670	1-2217214643-1	2011-09	UKAS147
Power Sensor	agilent	8481A	2702A57611	1-2217165866-1	2011-09	UKAS147
Power Meter	agilent	E4419B	GB43311917	1-2295928041-1A	2011-11	UKAS147
Set-Up "D" (100 kHz to 100 MHz)						
Calliper	Preisser	0-800mm	310121016	649724 DKD-K-12001 06-05	#	DKD
Power Sensor	agilent	8482A	2652A13544	08D177 DKD-K-02201 2008-06	2010-12	DKD
Power Meter	agilent	438A	2741U00723	1-1321958613-1A	2010-12	UKAS147
Attenuator	Weinschel	49-30-33	KC115	3248 DKD-K-00501 2008-06	2011-06	DKD

Reference standard; not used for routine calibration

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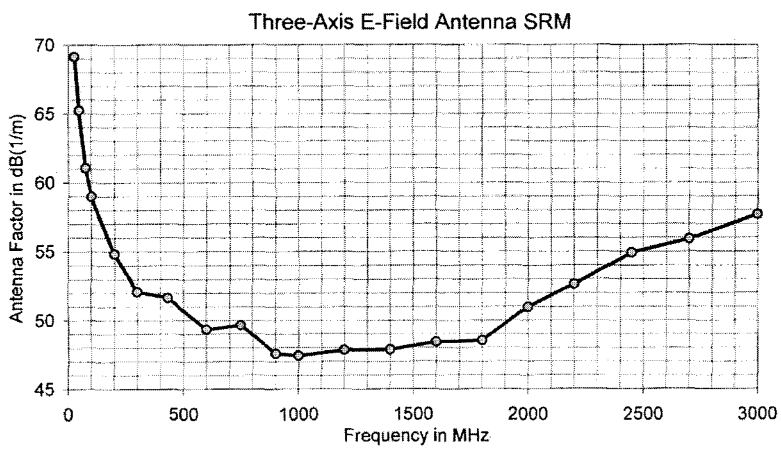
Results

Frequency Response passed

Frequency in MHz	E_applied in V/m	Output voltage in dB(µV)	Meas. Uncertainty in dB	Antenna Factor in dB(1/m)
26	10,0	70,85	1,0	69,15
45	10,0	74,76	1,0	65,24
75	10,0	78,95	1,0	61,05
100	10,0	81,00	1,0	59,00
200	10,0	85,17	1,0	54,83
300	10,0	87,92	1,0	52,08
433	10,0	88,36	1,5	51,64
600	10,0	90,66	1,5	49,34
750	10,0	90,35	1,5	49,65
900	10,0	92,45	1,5	47,55
1000	10,0	92,59	1,5	47,41
1200	10,0	92,20	1,5	47,80
1400	10,0	92,15	1,5	47,85
1600	10,0	91,60	1,5	48,40
1800	10,0	91,49	1,0	48,51
2000	10,0	89,04	1,0	50,96
2200	10,0	87,37	1,0	52,63
2450	10,0	85,11	1,0	54,89
2700	10,0	84,11	1,0	55,89
3000	10,0	82,34	1,0	57,66

Frequency Flatness (100 - 3000 MHz): 11,6 dB

The Antenna Factor data is permanently stored in the antenna connector memory.
The SRM basic unit uses this correction data to correct the display.



Appendix C

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Rotational Ellipticity **passed**

Frequency in MHz	Ellipse Ratio in dB
26	+/-0,13
45	+/-0,17
75	+/-0,12
100	+/-0,10
200	+/-0,10
300	+/-0,11
433	+/-0,11
600	+/-0,10
750	+/-0,15
900	+/-0,17
1000	+/-0,24
1200	+/-0,37
1400	+/-0,41
1600	+/-0,63
1800	+/-0,80
2000	+/-1,13
2200	+/-1,55
2450	+/-1,53
2700	+/-1,37
3000	+/-1,69

Output Return Loss **passed**

Appendix D

Calibration Certificate for the Narda EHP-50D Electric and Magnetic Field Analyzer

Appendix D

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Narda Safety Test Solutions S.r.l.
Sales & Support: Via Leonardo da Vinci 21/23
20090 Segrate (MI)
Tel.: +39 02 2699871 Fax: +39 02 26998700
Manufacturing Plant: Via Benessea, 29/B
17035 Cisano sul Neva (SV)
Tel.: +39 0182 58641 Fax: +39 02 586400

CERTIFICATE OF CALIBRATION
Certificato di taratura

Number *Numero* **10510**

Item *Oggetto*	Electric and Magnetic field Probe - Analyzer
Manufacturer *Costruttore*	Narda S.T.S. / PMM
Model *Modello*	EHP50D
Serial number *Matricola*	000WX10510
Calibration procedure *Procedura di taratura*	Internal procedure PTP 09-31
Date(s) of measurements *Data(e) delle misure*	23.06.2011
Result of calibration *Risultato della taratura*	Measurements results within specifications

This calibration certificate documents the traceability to national/international standards, which realise the physical units of measurements according to the International System of Units (SI). Verification of traceability is guaranteed by mentioning used equipment included in the measurement chain. This equipment includes reference standard directly traceable to (inter)national standard (accuracy rating A) and working standard calibrated by the calibration laboratory of Narda Safety Test Solutions (accuracy rating B) by means of reference standard A or by other calibration laboratory.
The measurement uncertainties stated in this document are estimated at the level of twice the standard deviation (corresponding, in the case of normal distribution, to a confidence level of about 95%). The uncertainties are calculated in conformity to the ISO Guide (Guide to the expression of uncertainty in measurement).The metrological confirmation system for the measuring equipment used is in compliance with ISO 10012-1. The applied quality system is certified to UNI EN ISO 9001.
Questo certificato di taratura documenta la tracciabilità a campioni primari nazionali o internazionali i quali realizzano la riferibilità alle unità fisiche del Sistema Internazionale delle Unità (SI). La verifica della tracciabilità è garantita elencando gli strumenti presenti nella catena di misura.La catena di riferibilità metrologica fa riferimento a campioni di prima linea direttamente riferiti a standard (inter)nazionali (classe A), di seconda linea, tarati nel laboratorio metrologico della Narda Safety Test Solutions con riferibilità ai campioni di prima linea oppure tarati da Enti esterni accreditati (classe B).
Le incertezze di misura dichiarate in questo documento sono espresse come due volte lo scarto tipo (corrispondente, nel caso di distribuzione normale, a un livello di confidenza di circa 95%). Le incertezze di misura sono calcolate in riferimento alla guida ISO. La conferma metrologica della strumentazione usata è conforme alla ISO 10012-1. Il sistema di qualità è certificato ISO 9001.

COMPANY WITH QUALITY MANAGEMENT SYSTEM CERTIFIED BY DNV
= ISO 9001:2000 =

Date of issue *Data di emissione*	**Measure operator** *Operatore misure*	**Person responsible** *Responsabile*
28.06.2011	F. Ferrari OPERATORE n. 03	G. Basso

The calibration was carried out at an ambient temperature of (23 ± 3)°C and at a relative humidity of (50 +10/-20)%.

Calibration method

The magnetic calibration was set up with the probe in a region of uniform magnetic field at the centre of a calibrated Helmholtz coil system. The magnetic flux density is calculated from the current flowing in the coil. The current waveform was sinusoidal. The current in the Helmholtz coil system was adjusted to produce a series of indicated magnetic flux densities on the instrument at various frequencies. The calibration procedure agrees with the indication of IEC 61786 "Measurement of low frequency magnetic and electric fields with regard to exposure of human beings- Special requirements for instruments"
The instrument readings were recorded and the actual values of magnetic flux density were calculated from the measured currents.
The magnetic correction factor (CF) is defined as rapport between actual and indicated magnetic flux density.

$$CF = \frac{Bo}{Bmis}$$

where Bo is the applied magnetic flux density and Bmis is the indicated magnetic flux density

For the electric calibration the probe is positioned inside a big TEM cell (section 1.8x1.8 mete
For each measurement, the input voltage was adjusted so that the field strength was set to a specified reading on the monitor.
The actual field strength, at the plane of reference of the probe was then determined and the correction factor calculated using the following definition.

$$CF = \frac{Eo}{Emis}$$

where Eo is the applied field strength and Emis is the indicated field strength

The correction factor data are permanently stored in the internal EEPROM.

Calibration equipment and traceability

ID Number	Description	Manufacturer	Model	Trace
PMM 391	Digital multimeter	Agilent	34401A	/SIT
CMR 169	Electric and Magnetic ref. Probe	Narda	EHP50C-REF	/INRIM
CMR 090	Standard resistor	Narda	PMM BSD250	/NPL
CMR 095	Current Trasformer	Frer	AP10-1TAC010	/INRIM
CMR 001	TEM Cell	Narda	1818	/Narda
CMR 020	Helmholtz coil	Narda	HCSS001	/Narda

Uncertainty of measurements

The statement of uncertainty (see first page) does not make any implication or include any estimation as to the long term stablity of the calibrated monitor. The relative expanded uncertainty result are given below

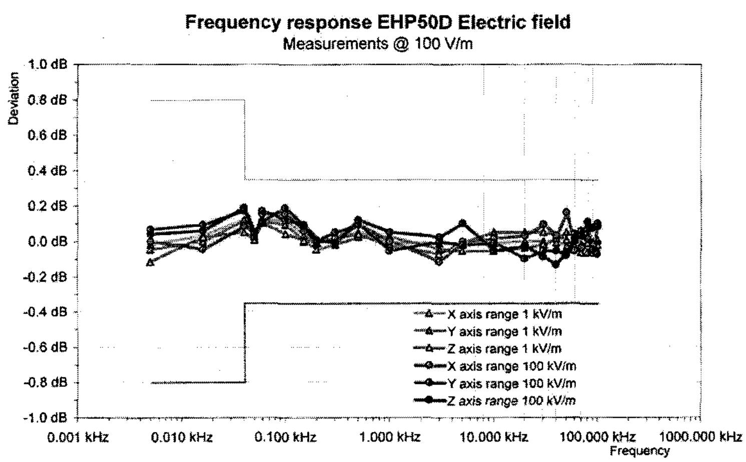
E field	3% at 50 Hz
	7.5% other frequencies
H field	2% at 50 Hz with 100μT range
	3.5% at 50 Hz with 10mT range
	3% other frequencies

Results

The results of measurements in the following pages were obtained after calibration data storing and indicates the residual of the reciprocal CF.
The results given on the tables were obtained with the axis aligned at the electric vector for electric measurements and with axis concatenated at the magnetic flux density for magnetic mesurements
The shown limits of the EHP50D specification in the diagrams are in orange.

Electric field *Frequency response for each axis at nominal field of 100 V/m.*
The instrument was set as electric field measure with 100 Hz span up to the frequency of 100 Hz, 200 Hz span up to the frequency of 200 Hz, 500 Hz span up to the frequency of 500 Hz, 1 kHz up to 1000 Hz, 10 kHz up to 10 kHz and 100 kHz span for frequency over 10 kHz

Freq. (kHz)	Deviation with 1kV/m range			Deviation with 100 kV/m range		
	X axis (dB)	Y axis (dB)	Z axis (dB)	X axis (dB)	Y axis (dB)	Z axis (dB)
0.005	-0.02	-0.04	-0.11	0.00	0.07	0.04
0.016	0.03	0.00	0.03	-0.04	0.10	0.06
0.04	0.12	0.12	0.05	0.09	0.17	0.19
0.05	0.03	0.03	0.01	0.04	0.03	0.05
0.06	0.11	0.11	0.10	0.15	0.17	0.11
0.10	0.12	0.10	0.04	0.15	0.12	0.19
0.15	0.03	0.00	0.01	0.06	0.10	0.09
0.20	-0.01	-0.04	0.00	0.00	0.01	0.01
0.30	0.02	-0.02	0.02	0.02	0.05	-0.01
0.50	0.05	0.03	0.04	0.10	0.10	0.12
1.00	-0.01	0.03	-0.03	0.00	-0.05	0.05
3.00	-0.01	-0.04	-0.07	-0.11	0.00	0.03
5.00	-0.02	-0.05	-0.01	0.00	-0.02	0.10
10.00	-0.01	-0.05	0.05	0.02	-0.01	-0.05
20.0	0.00	-0.03	0.05	0.03	-0.10	-0.03
30.0	0.00	-0.02	0.05	0.10	-0.05	-0.09
40.0	-0.01	0.02	0.03	0.03	-0.05	-0.13
50.0	-0.03	0.05	0.01	0.16	-0.08	-0.06
60.0	0.01	0.02	-0.03	-0.05	0.04	0.02
70.0	0.03	-0.02	-0.06	-0.03	0.06	0.03
80.0	-0.01	-0.06	0.03	0.02	0.07	0.11
90.0	-0.06	0.00	-0.03	-0.02	-0.04	0.08
100.0	-0.05	0.01	-0.02	0.10	-0.07	0.09

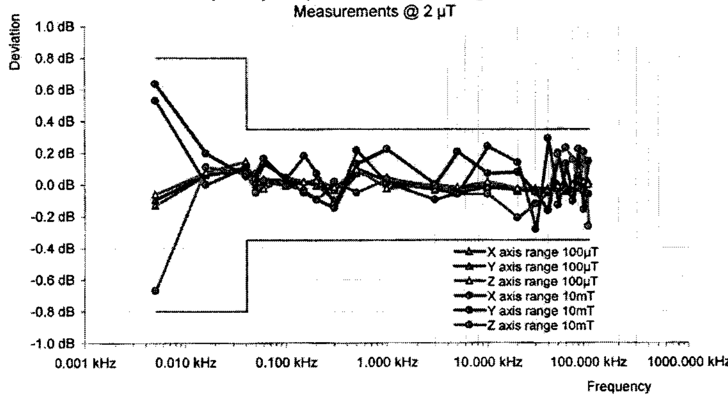


EHP50D_Narda-Certificate of Calibration_r01_000WX10510.xls narda Safety Test Solutions

Magnetic Field Frequency response for each axis at nominal magnetic flux density of 2µT.
The instrument was set as magnetic field measure with 100 Hz span up to the frequency of 100 Hz, 200 Hz span up to the frequency of 200 Hz, 500 Hz span up to the frequency of 500 Hz, 1 kHz up to 1000 Hz, 10 kHz up to 10 kHz and 100 kHz span for frequency over 10 kHz

Freq. (kHz)	Deviation with 100µT range			Deviation with 10mT range		
	X axis (dB)	Y axis (dB)	Z axis (dB)	X axis (dB)	Y axis (dB)	Z axis (dB)
0.005	-0.13	-0.10	-0.06	0.53	0.64	-0.67
0.016	0.06	0.06	0.08	0.00	0.20	0.11
0.04	0.11	0.09	0.15	0.11	0.05	0.07
0.05	-0.02	0.02	-0.03	0.03	0.07	-0.05
0.06	0.02	0.03	-0.03	0.13	0.16	0.03
0.10	-0.01	0.03	0.04	0.04	0.03	-0.01
0.15	0.02	0.02	0.02	0.18	-0.05	-0.03
0.20	-0.01	-0.01	0.03	0.07	-0.10	-0.10
0.30	-0.10	-0.03	-0.02	-0.13	-0.15	0.02
0.50	0.07	0.10	0.10	0.21	0.13	-0.05
1.00	0.04	0.02	-0.03	0.01	0.22	0.03
3.00	-0.03	-0.03	0.00	-0.10	0.00	-0.01
5.00	-0.03	-0.05	-0.02	-0.05	0.21	-0.06
10.00	0.00	-0.02	0.02	0.24	0.07	-0.06
20.0	-0.04	-0.03	-0.03	0.14	0.08	-0.21
30.0	-0.03	-0.04	-0.03	-0.28	-0.05	-0.12
40.0	-0.03	-0.05	-0.03	0.29	-0.17	-0.05
50.0	0.00	-0.03	-0.01	-0.13	0.20	0.19
60.0	-0.01	-0.04	-0.01	0.13	-0.03	0.23
70.0	-0.02	-0.03	0.00	-0.10	-0.07	0.15
80.0	-0.02	0.00	-0.02	0.05	0.22	-0.03
90.0	-0.03	-0.03	0.02	-0.04	-0.16	0.21
100.0	0.02	0.00	0.00	0.15	-0.06	-0.26

Frequency response EHP50D Magnetic field
Measurements @ 2 µT



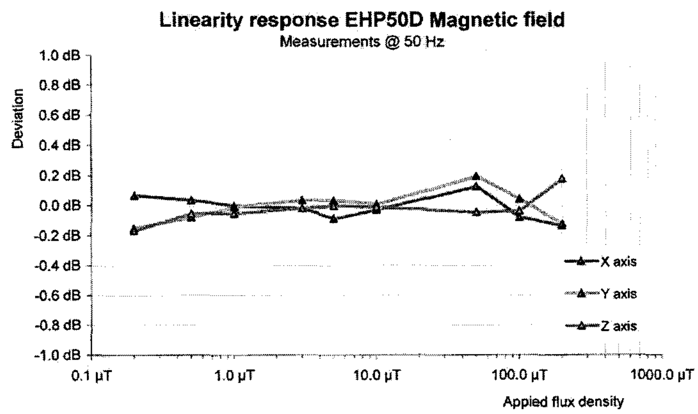
EHP50D_Narda-Certificate of Calibration_r01_000WX10510.xls

Appendix D

Magnetic Field Linearity response for each axis at applied frequency of 50 Hz and magnetic flux density below
The instrument was set with 100 Hz span.

Applied flux density (µT)	Deviation		
	X axis (dB)	Y axis (dB)	Z axis (dB)
0.2	0.07	-0.15	-0.17
0.5	0.03	-0.08	-0.05
1.0	0.00	-0.01	-0.05
3.0	-0.02	0.03	-0.02
5.0	-0.09	0.03	0.00
10	-0.03	0.01	-0.01
50	0.13	0.20	-0.04
100	-0.08	0.04	-0.03
200	-0.13	-0.12	0.18

X axis linearity 0.13 dB
Y axis linearity 0.17 dB
Z axis linearity 0.17 dB



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Determining the Recalibration Due Date

Determinazione della data di ricalibrazione

The Certificate of Calibration accompanying this product states the date that this unit was calibrated according to Narda Safety Test Solutions procedures. We have determined that the calibration of this product is not affected by storage prior to its initial receipt by the customer.
The recalibration of this unit should be based on the date when the product is put into service, plus the recommended calibration interval.

The Narda Safety Test Solutions recommended calibration interval is 24 months. To determine the date for recalibration, the customer should use the appropriate start date, and apply either the Narda Safety Test Solutions calibration interval, or an interval that satisfies their own organization's internal quality system requirements.

Il certificato di taratura che accompagna questo strumento attesta la data di taratura, quest'ultima eseguita in accordo alle procedure interne. La Narda Safety Test Solutions assicura che la taratura dello strumento non viene alterata da eventuali tempi di attesa prima del ricevimento da parte del cliente.
La ri-taratura di questo strumento dovrebbe essere effettuata adottando appropriati intervalli di taratura, a partire dalla data di messa in servizio.

La Narda Safety Test Solutions raccomanda un massimo intervallo di taratura di 24 mesi. Per determinare la data di ri-taratura, l'utente dovrebbe considerare l'intervallo raccomandato dalla Narda Safety Test Solutions o un intervallo che soddisfa i requisiti interni di qualità della propria organizzazione.

Model *Modello*	EHP 50 D
Serial Number *Matricola*	000WX10510
Put into service date *Data di messa in servizio*	05/15/2012

For additional information please contact
Per informazioni aggiuntive

Narda S.T.S. Calibration Laboratory
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Appendix E

Calibration Certificate for the Comparison SRM-3006 Probe/Antenna

Appendix E

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Calibration Certificate

Narda Safety Test Solutions hereby certifies that the object referred to in this certificate has been calibrated by qualified personnel using Narda's approved procedures. The calibration was carried out in accordance with a certified quality management system which conforms to ISO 9001

OBJECT	Three-Axis-Antenna, E-Field, 50 MHz to 3 GHz
MANUFACTURER	Narda Safety Test Solutions GmbH
PART NUMBER (P/N)	P/N 3501/02
SERIAL NUMBER (S/N)	H-0368
CUSTOMER	
CALIBRATION DATE	27-Okt-2011
RESULT ASSESSMENT	within specifications
AMBIENT CONDITIONS	Temperature (23 ± 3) °C Relative humidity (20 to 60) %
CALIBRATION PROCEDURE	3000-8702-00A

ISSUE DATE 2011-10-27

MANAGEMENT SYSTEM

CALIBRATED BY
Kretschmann

AUTHORIZED SIGNATORY

Certified by DQS against ISO 9001 2008 (Reg.-No. 099379 QM08)

Appendix F

Integration of RF Spectra Acquired on the SRM-3006

Appendix F

SRM-3006 Spectrum Signal Integration

The SRM-3006 Selective Radiation Meter is a fast Fourier transform (FFT) type of analyzer. Rather than using traditional analog frequency sweeping technology in which the instrument tunes from a lower frequency to a higher frequency, the SRM samples the RF signal provided to it from the associated probe/antenna subsystem for a short period of time using an ultra-fast analog to digital converter. Upon Fourier transform of the time series data, this process produces a data set of signal amplitudes at frequencies distributed uniformly through the desired analysis band. The number of such frequencies (bins) depends on the overall frequency span and the resolution bandwidth (RBW) of the analyzer. The power associated with a given signal detected by the instrument can be determined through an integration process in which the powers found within all of the frequency bins over the selected frequency range are, effectively, summed.

This integration process, which can be implemented via firmware within the SRM, can also be accomplished manually by processing each stored amplitude value corresponding to a frequency bin. This approach was taken for integrating the composite (equivalent) RF field represented by multiple signals detected in the various frequency bands during the project for environmental measurements in Vermont.

Based on information provided by Narda, the integrated spectral RF field, $F_{integrated}$, derived from the measured spectral amplitude components, F_i, is obtained through the expression:

$$F_{\text{integrated}} = M_B \sum_i F_i$$

where M_B are multiplicative factors that depend on the specific frequency span and RBW setting for a given band. For the various settings used with the SRM for different frequency bands, the multiplicative factor values are listed in Table F-1.

A spreadsheet macro was developed that applied this process to the measured spectral data obtained from the SRM; the stored digital data file within the SRM was downloaded to a computer and then inserted into the spreadsheet tool for integration. An important part of the process, however, was the implementation of a threshold to be used with each band's data below which integration did not take place. This feature eliminated the potential of adding in noise floor values to the integration process, thereby increasing the overall integrated value erroneously. The noise thresholds listed in Table F-1 were experimentally determined by observing the displayed spectrum of detected RF fields across each band and selecting a value that would just slightly exceed the noise level for peak and average signal values.

Table F-1. Parameters used for band integration of the measured RF field spectral signals from the SRM including the multiplicative factors, M_B, and thresholds used for integration of spectra containing the peak values of RF fields (max threshold) and average values of fields (average threshold).

BAND	Multiplicative Factor	Max threshold	Average threshold
Low VHF	0.493680853	0.000003000	0.000000600
FM	0.493680885	0.000000500	0.000000100
High VHF	0.493680853	0.000000700	0.000000200
UHF	0.473933649	0.000000350	0.000000080
Cell	0.473933649	0.000001000	0.000000200

Glossary

Glossary of Terms Used in this Report

AMI- Advanced metering infrastructure.

antenna- A device designed to efficiently convert conducted electrical energy into radiating electromagnetic waves in free space (or vice versa).

antenna pattern- Typically a graphical plot illustrating the directional nature of radiated fields produced by an antenna. The pattern also shows the directional nature of the antenna when used for receiving signals.

attenuation- The phenomenon by which the amplitude of an RF signal is reduced as it moves from one point in a system to another. It is often given in decibels.

averaging Time (T_{avg})- The appropriate time period over which exposure is averaged for purposes of determining compliance with the maximum permissible exposure (MPE). For exposure durations less than the averaging time, the maximum permissible exposure, MPE', in any time interval, is found from:

$$MPE = MPE\left(\frac{T_{avg}}{T_{exp}}\right)$$

where T_{exp} is the exposure duration in that interval expressed in the same units as T_{avg}. T_{exp} is limited by restriction on peak power density.

azimuth pattern- Commonly a term referring to an antenna pattern showing the distribution of radiated field from the antenna in the azimuth plane (horizontal plane).

bandwidth- A measure of the frequency range occupied by an electromagnetic signal. It is equal to the difference between the upper frequency and the lower frequency, usually expressed in Hertz.

burst- A wave or waveform composed of a pulse train (group of pulses) or repetitive waveform that starts at a prescribed time and/or amplitude, continues for a relatively short duration and/or number of cycles, and upon completion returns to the starting amplitude.

calibration correction factor- A numerical factor obtained through a calibration process that is used to multiply RF field meter readings by to obtain corrected readings to achieve the maximum accuracy possible.

Glossary

continuous exposure- Exposure for durations exceeding the corresponding averaging time (usually 6 minutes for occupational exposure and 30 minutes for the general public). Exposure for less than the averaging time is called short-term exposure.

dBi- Decibel referenced to an isotropic antenna- a theoretical antenna which transmits (or receives) electromagnetic energy uniformly in all directions (i.e. there is no preferential direction).

dBm- A logarithmic expression for radiofrequency power where 0 dBm is defined as equal to 1 milliwatt (mW). Hence, +10 dBm is 10 mW, +20 dBm is 100 mW, etc., and -10 dBm is 0.1 mW.

decibel (dB)- A dimensionless quantity used to logarithmically compare some value to a reference level. For power levels (watts or watts/m^2), it would be ten times the logarithm (to the base ten) of the given power level divided by a reference power level. For quantities like volts or volts per meter, a decibel is twenty times the logarithm (to the base ten) of the ratio of a level to a reference level.

direct sequence- As used in direct sequence spread spectrum radio transmission, a modulation technique wherein the resulting transmitted bandwidth of a signal is spread over a much wider band and resembles white noise.

duty cycle- A measurement of the percentage or fraction of time that an RF field exists over some observation period.

effective isotropic radiated power (EIRP)- The apparent transmitted power from an isotropic antenna (i.e. a theoretical antenna that transmits uniformly in all possible directions as an expanding sphere). The EIRP can be greater than the actual power radiated because of the ability of the antenna to concentrate the transmitted power in certain directions. See gain.

electric field strength- A field vector (E) describing the force that electrical charges have on other electrical charges, often related to voltage differences, measured in volts per meter (V/m).

electromagnetic field- A composition of both an electric field and a magnetic field that are related in a fixed way that can convey electromagnetic energy. Antennas produce electromagnetic fields when they are used to transmit signals.

electromagnetic spectrum- The range of frequencies associated with electromagnetic fields. The spectrum ranges from extremely low frequencies beginning at zero hertz to the highest frequencies corresponding to cosmic radiation from space.

elevation pattern- Commonly a term referring to an antenna pattern showing the distribution of radiated field from the antenna in the elevation plane (vertical plane).

end point meter- A term used to designate a smart meter that is installed on a home or business to record and transmit electric energy.

exposure- Exposure occurs whenever a person is subjected to electric, magnetic or electromagnetic fields or to contact currents other than those originating from physiological processes in the body and other natural phenomena.

far field- The far field is a term used to denote the region far from an antenna compared to the wavelength corresponding to the frequency of operation. It is a distance from an antenna beyond which the transmitted power densities decrease inversely with the square of the distance.

Federal Communications Commission (FCC)- The Federal Communications Commission (FCC) is an independent agency of the US Federal Government and is directly responsible to Congress. The FCC was established by the Communications Act of 1934 and is charged with regulating interstate and international communications by radio, television, wire, satellite, and cable. The FCC also allocates bands of frequencies for non-government communications services (the NTIA allocates government frequencies). The guidelines for human exposure to radio frequency electromagnetic fields as set by the FCC are contained in the Office of Engineering and Technology (OET) Bulletin 65, Edition 97-01 (August 1997). Additional information is contained in OET Bulletin 65 Supplement A (radio and television broadcast stations), Supplement B (amateur radio stations), and Supplement C (mobile and portable devices).

FFT- Fast Fourier Transform, a mathematical method for transforming data acquired in the time domain into the frequency domain. Some modern spectrum analyzers use high speed analog to digital converters (ADCs) to sample an input signal in the time domain and electronically implement the FFT to calculate and display the frequency spectrum of the sampled signal(s).

free space- A term used to denote an environment free of objects that can reflect, scatter or absorb RF energy. Anechoic chambers can provide free space environments that eliminate most reflections when testing antennas.

frequency hopping- A term describing the transmission frequency of a spread spectrum transmitter or transceiver that jumps (hops) instantaneously to different frequencies within a certain band of frequencies.

gain, antenna- A measure of the ability of an antenna to concentrate the power delivered to it from a transmitter into a directional beam of energy. A search light exhibits a large gain since it can concentrate light energy into a very narrow beam while not radiating very much light in other directions. It is common for cellular antennas to exhibit gains of 10 dB or more in the elevation plane, i.e., concentrate the power delivered to the antenna from the transmitter by a factor of 10 times in the direction of the main beam giving rise to an effective radiated power greater than the actual transmitter output power. In other directions, for example, behind the antenna, the antenna will greatly decrease the emitted signals. Gain is often referenced to an isotropic antenna (given as dBi) where the isotropic antenna has unity gain (unity gain is equivalent to 0 dBi). At regions out of the main beam of an antenna, such as behind the antenna in a smart meter, the gain of the antenna may be so small that it is less than that of an isotropic antenna and has a gain specified as a negative dBi.

gigahertz (GHz)- One billion hertz.

ground reflection factor- A factor commonly used in calculations of RF field power densities that expresses the power reflection coefficient of the ground over which the RF field is being computed. The purpose of the factor is to account for the fact that ground reflected RF fields can add constructively in an enhanced (stronger) resultant RF field. The ground reflection factor becomes significantly less important for near-field exposures very close to an RF source, such as a smart meter.

HAN- See home area network

hertz- The unit for expressing frequency, one hertz (Hz) equals one cycle per second.

Home Area Network- A term that refers to residential local area network for communication between digital devices typically deployed in the home, commonly implemented by way of a ZigBee radio.

IEEE- Institute of Electrical and Electronics Engineers.

inverted F antenna- The name given to an antenna design typically implemented on printed circuit cards in which the conductive part of the antenna resembles an inverted letter F. The antenna is typically approximately a quarter wavelength long and is fed from the attached transmitter near the end of the antenna that has a short conductive lead that extends from the longer part of the 'F' to the ground plane of the circuit. The antenna is vertically polarized when the long aspect of the 'F' is horizontal.

isotropic antenna- A theoretical antenna which transmits (or receives) electromagnetic energy uniformly in all directions (i.e. there is no preferential direction). The radiated wavefront is assumed to be an expanding sphere.

isotropic probe- Similar to isotropic antenna but normally related to RF measurement instruments designed to evaluate the magnitude of RF fields from a safety perspective. The isotopic character of the probe results in a measurement of the resultant RF field produced by all polarization components.

"license free"- A phrase meaning that an RF transmitter is operated at such low power and within an authorized frequency band that no formal license to operate is required by the FCC. There are restrictions placed on these devices, however, such as they shall not produce interference and/or may not create RF fields exceeding particular field strengths.

lobe, antenna- The name given to regions of an antenna transmitting pattern in which local maxima of the radiated field exist. See main lobe.

local oscillator zero feed through- A characteristic of mixer circuits, typically used in spectrum analyzers, wherein the local oscillator signal is coupled into the intermediate frequency (IF) path due to its limited isolation. As an example, if very low frequency input signals are converted by the mixer, the first IF can be very nearly zero Hz and with relatively large resolution bandwidth, the local oscillator signal is sent to the detector and displayed at zero Hz. This is an extraneous signal that is not related to the actual amplitude of the very low frequency input signal.

Main beam- see main lobe.

main lobe- A region of the transmitting pattern of an antenna in which the greatest intensity exists, also called the main beam of the antenna.

max hold spectrum- A feature often present on instruments such as spectrum analyzers in which the instantaneous peak values of measured signals are captured and continuously displayed so that, over time, the absolute maximum signal values can be determined even if they were only present for a short period.

maximum permissible exposure (MPE)- The rms and peak electric and magnetic field strength, their squares, or the plane wave equivalent power densities associated with these fields and the induced and contact currents to which a person may be exposed without harmful effect and with an acceptable safety factor.

megahertz (MHz)- One million hertz.

mesh network- A term describing a network, typically wireless, in which multiple nodes communicate among themselves and data can be relayed via various nodes to some access point. Mesh networks are self healing in that should a particular pathway become nonfunctional for some reason, alternative paths are automatically configured to carry the data. Mesh networks can expand beyond the normal range of any single node (smart meter) by relaying of data among the different meters.

microwatts- One-millionth of a watt, a microwatt (μW) or 10^{-6} watts.

modulation- Refers to the variation of either the frequency or amplitude of an electromagnetic field for purposes of conveying information such as voice, data or video programming.

near field- A region very near antennas in which the relationship between the electric and magnetic fields is complex and not fixed as in the far field, and in which the power density does not necessarily decrease inversely with the square of the distance. This region is sometimes defined as closer than about one-sixth of the wavelength. In the near field region the electric and magnetic fields can be determined, independently of each other, from the free-charge distribution and the free-current distribution respectively. The spatial variability of the near field can be large. The near field predominately contains reactive energy that enters space but returns to the antenna (this is different from energy that is radiated away from the antenna and propagates through space).

nearfield coupling- A phenomenon that can occur when an RF measurement probe is placed within the reactive near field of an RF source such that the probe interacts strongly with the source in a way that typically draws power from the source than would not occur at greater distances. When nearfield coupling occurs, field probe readings are typically erroneously greater than the actual RF field magnitude. For this reason, an IEEE measurement standard (C95.3) recommends a minimum spacing between source and sensor of 20 cm.

planar scan- In the context of this study, a spatial scan over a plane in front of a smart meter or a group of smart meters at a fixed distance from the smart meters.

plane wave- Wave with parallel planar (flat) surfaces of constant phase (See also Spherical wave). Note: The cover of this report shows an idealized spherical wave that expands outward- in an appropriate region that this spherical wave can be considered as a plane (flat) wave.

polarization- The orientation of the electric field component of an electromagnetic field relative to the earth's surface. Vertical polarization refers to the condition in which the electric field component is vertical, or perpendicular, with respect to the ground, horizontal polarization refers to the condition in which the electric field component is parallel to the ground.

power density- Power density (S, sometimes called the Poynting vector) is the power per unit area normal to the direction of propagation, usually expressed in units of watts per square meter (W/m^2) or, for convenience, milliwatts per square centimeter (mw/cm^2) or microwatts per square centimeter ($\mu w/cm^2$). For plane waves, power density, electric field strength, E, and magnetic field strength, H. are related by the impedance of free space, i.e. 120π (377) ohms. In particular, $S = E^2/120\pi = 120\pi H^2$ (Where E and H are expressed in units of V/m and A/m, respectively, S is in units of $W/m^{2)}$. Although many RF survey instruments indicate power density units, the actual quantities measured are E or E^2 or H or H^2.

pulse- A brief presence of an RF signal (field).

radiation pattern- A description of the spatial distribution of RF energy emitted from an antenna sometimes referred to as transmitting pattern. Two radiation patterns are required to completely describe the transmitting performance of an antenna, one for the azimuth plane and another for the elevation plane.

radio- A term used loosely to describe a radio transmitter or transceiver.

radio frequency (RF)- Although the RF spectrum is formally defined in terms of frequency as extending from 0 to 3000 GHz, the frequency range of interest is 3 kHz to 300 GHz.

radio spectrum- The portion of the electromagnetic spectrum with wavelengths above the infrared region in which coherent waves can be generated and modulated to convey information- generally about 3 kHz to 300 GHz.

RBW- see resolution bandwidth.

reflection- An electromagnetic wave (the "reflected" wave) caused by a change in the electrical properties of the environment in which an "incident" wave is propagating. This wave usually travels in a different direction than the incident wave. Generally, the larger and more abrupt the change in the electrical properties of the environment, the larger the reflected wave

resolution bandwidth- A specification for spectrum analyzers that denotes the ability of the analyzer to identify two signals on different frequencies, a measure of the frequency selectivity of the analyzer.

resultant field- The combined result of all polarization components of an electromagnetic field found by determining the sum of three orthogonal components of power density or the root sum squared of three orthogonal components of electric or magnetic field strength.

Glossary

RF - Radiofrequency.

RF LAN- A term representing a local area network formed by wireless nodes. In the case of smart meters, the 900 MHz band radios communicate with one another forming an RF LAN.

root-mean-square (RMS)- The effective value of, or the value associated with joule heating, of a periodic electromagnetic wave, current or voltage. The RMS value of a wave is obtained by taking the square root of the mean of the squared value of the wave amplitude.

shielding effectiveness- A measure of the ability of a material or structure to attenuate RF fields, typically specified in decibels.

spatial average- For RF exposure limits, a determination of the average value of power density over the projected cross section area of the body. In practice, an average along a vertical line representing the height of a person.

specific absorption rate (SAR)- The time derivative of the incremental energy absorbed by (dissipated in) an incremental mass contained in a volume) of a given density. SAR is expressed in units of watts per kilogram (W/kg) or milliwatts per gram (mW/g). Guidelines for human exposure to radio frequency fields are based on SAR thresholds where adverse biological effects may occur. When the human body is exposed to a radio frequency field, the SAR experienced is proportional to the squared value of the electric field strength induced in the body. Compliance with RF exposure limits for devices that are intended to be placed, in normal use, closer than 20 cm of the body surface, are evaluated by a direct measurement of the local SAR within the body at the point of maximum exposure. In the case of cell phones, this is usually at the side of the head and is accomplished through the use of a phantom model that simulates the size and shape of the human body and contains a liquid that has electrical properties comparable to human body tissues.

spectrum analyzer- An electronic instrument, similar to a receiver, that sweeps across a part of the RF spectrum and displays detected signals as peaks on a visual display screen. Spectrum analyzers normally continuously sweep repetitively over a given frequency band at a relatively high rate thereby allowing for the observation of intermittent signals.

spread spectrum- Refers to a method by which an RF signal that is generated in a particular bandwidth is deliberately spread in the frequency domain resulting in a signal with a wider bandwidth. Such a technique is used to enhance secure communications, to reduce interference and to prevent detection.

sweep time- In an oscilloscope or spectrum analyzer, the time spent to sweep across either the time or frequency axis in the measurement of signals. Typically, the amount of time it takes to perform a defined measurement before starting the next measurement. Commonly, the instrument is set to continuously and repetitively update the measurement according to its sweep time.

switch mode power supply (SMPS)- A power supply design that incorporates solid state switching elements that significantly increase power conversion efficiency when converting AC to DC. In an SMPS, the input line voltage is typically rectified and applied to the switching element in the supply that chops or switches the DC current at a high frequency. This process, which effectively increases the frequency of input voltage of the supply, results in much smaller component sizes needed for a transformer and associated capacitors for filtering of the output DC voltage. Typically, a feedback signal from the SMPS output is also used to generate a pulse width modulated signal for regulating the supply output voltage.

time-averaged exposure- In the context of RF exposure limits, an average of the exposure value over a specified time period. Commonly, for occupational exposures, the averaging time is six-minutes and for members of the general public 30-minutes. All scientifically based RF exposure limits are in terms of time-averaged values.

time resolution- In a display of signal amplitude vs. time, the incremental time interval (window) within which an instrument samples the instantaneous peak and average values of signals prior to display. The smaller the time resolution, the better the instrument can indicate the time at which signals occurred. Larger time resolutions do not mean that the instrument necessarily does not detect narrow signal pulses, only that it may not indicate the exact time of occurrence during the time resolution window.

transceiver- A radio device that has both transmitting and receiving capability. Strictly, the radio devices in Smart Meters are transceivers since they can both transmit data and receive data. Commonly, in the context of evaluating RF fields, the term transmitter or radio is used to refer to the transmitting feature of the transceiver.

ZigBee radio- A radio transceiver inside some smart meters that allows communications with an in-home-device (IHD) for displaying electric energy consumption data. The radio operates in the 2.4-2.5 GHz license free band often used by wireless routers, some cordless telephones and other devices and can be used in a home area network (HAN). The term ZigBee refers to a set of high level digital communication protocols based on an IEEE 802 standard for personal area networks.

Summary

Besides the RF LAN that operates in the 900 MHz region, an additional radio is contained in both the GMP and BED meters that, in the future, can be used to facilitate home area networks (HANs) at customer homes. A HAN, utilizing radios that operate in the 2.4 GHz band, will allow, for example, the customer to observe in real time their residential consumption of electric energy. This feature had not been implemented within the BED service territory at the time of the field measurements but GMP has a pilot project of evaluating customer reactions to a HAN in a sample of residences in the Rutland area. During this study, it was observed that all GMP meters emitted short, infrequent RF pulses from the HAN radios though some 500 meters were commissioned to communicate with in home display (IHD) devices. Hence, field measurements included determining the same characteristics for the HAN radio emissions in Rutland as was performed for the RF LAN emissions.

RF fields were measured as a function of distance in front of smart meters and throughout most of the homes to which the meters were attached. The measurement approach involved detecting the instantaneous peak value of the pulsed RF fields emitted by smart meters to examine how the RF field decreases with distance from the meter. Separately, strategic measurements were made to assess the duty cycle of meter emissions at many locations with a focus on determining the greatest duty cycle that could be achieved. The duty cycle of a smart meter is a measure of how the average value of RF field is related to the peak value of RF field. By knowing the duty cycle, the peak values could be adjusted to arrive at their corresponding time-averaged values. Field work in Vermont was supplemented with measurements on two test meters provided by GMP and BED in Colville, WA. Many measurements were performed over half-hour periods, both in Vermont and in Colville; 30 minutes is the averaging time specified in the FCC RF exposure regulations.

As a means for forming a perspective on potential smart meter RF exposures, additional measurements of ambient levels of FM radio and television (TV) broadcast signals as well as mobile phone base station signals were made in Rutland, Burlington, Montpelier and Saint Albans, VT. Additionally, as the opportunity presented itself, limited measurements were also made of RF emissions of microwave ovens, wireless routers used for distribution of Internet connectivity and a mobile phone. Azimuth and elevation plane patterns of RF emissions of the smart meters were determined and measurements were made of low frequency electric and magnetic fields from 0 to 100 kHz with the test meters in Colville.

Measurement data collected during the project support the following conclusions in regard to potential exposure associated with the smart meters investigated in Vermont:

- The instantaneous peak value of RF field, during the pulses, may be as high as 3.9% of the MPE at the closest distance measured of one foot.